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CONTENTS

The Chicago Convention, June 12–16, 1933

Part I

Main Session

Some Interesting Phases of Chicago's Water Works Activities. By Myron B. Reynolds 1321

Underground Street Leakage in Chicago Distribution System. By J. B. Eddy and B. Phillips 1339

Special Low-Heat Cement for Mass Concrete Dams. By Samuel B. Morris 1350

Ground-Level Storage and Booster Station at Milwaukee, Wisconsin. By Herbert H. Brown 1362

Twenty Years Progress in Centrifugal Water Works Pumps. By A. Peterson 1372

Bituminous Pipe Coatings. By William M. Wallace and James A. Parks 1387

Promiscuous Electric Grounding on Water Service Pipes and Mains. By Nicholas S. Hill, Jr., C. F. Meyerherm and M. W. Cowles 1418

Some Modern Methods of Coating and Lining Pipe. By Linden Stuart 1431

Errors and Omissions—Seventh Edition, Standard Methods for the Examination of Water and Sewage 1443

Abstracts 1445

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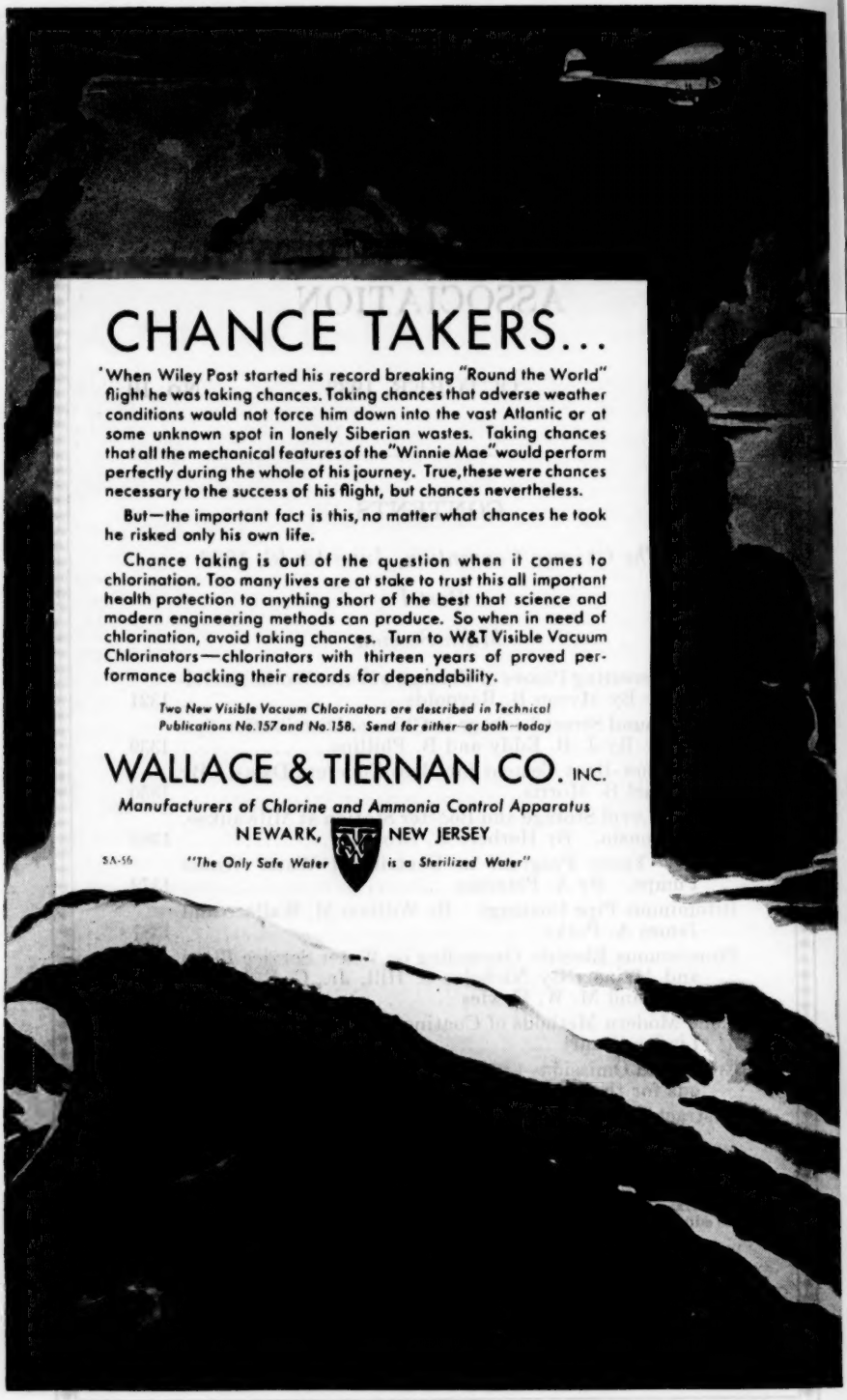
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Vol. 25 OCTOBER, 1933 No. 10

SOME INTERESTING PHASES OF CHICAGO'S WATER WORKS ACTIVITIES

By Myron B. Reynolds

(City Engineer, Chicago, Ill.)

Every water works system has its interesting problems in design, construction and operation, as well as in its consumption and revenue characteristics. The Chicago system is no exception; but because of its size and the fact that Lake Michigan water is pumped directly to the consumer without treatment (except chlorination) and without intermediate storage, its problems are, in many instances, unique and of special interest to engineers.

With its six intake cribs, about 63 miles of tunnels in service, twelve pumping stations, 3700 odd miles of cast iron mains and about 422,000 services of all classes including 34 suburban towns and representing a combined population of nearly 4,000,000 people, our water works must be equipped to handle emergencies of all types and we must be continuously studying its existing system as well as planning for the future. In this work we have encountered numerous interesting problems, a few of which will be briefly discussed.

SURGES IN TUNNELS

In a system of tunnels and pumping stations so extensive as Chicago's and where the feeding tunnels are connected to serve several stations from the same tunnel or tunnels, it often occurs

that different types of pumping machinery are in use simultaneously; some of these, such as turbine or motor driven centrifugals, can and do cause serious surges where the turbine "kicks off," or there are interruptions in the power supply to the motors.

The Wilson Avenue tunnel system is such an example. Here the Lake View station is entirely triple expansion driven; the Thomas Jefferson station is entirely motor driven; and the Mayfair station is both triple expansion and turbine driven.

The Thomas Jefferson station lies between the Lake View and Mayfair stations, and when pumping at its rated capacity of 120 m.g.d. will, in event of an interruption in power service, cause surge waves to occur in excess of 25 feet at the Mayfair station which is at the extremity of the tunnel system. Practically the same disturbance will also occur at the Lake View station.

To date the Thomas Jefferson, put into service in 1928, has given trouble only once. This time it was under very light load, pumping only 45 m.g.d. Nevertheless the results of rejecting even this small load caused practically all triple expansion engines to race badly and produced what can be really called a dangerous condition.

Fortunately there is sufficient shaft area in this system to function satisfactorily as surge chambers with the exception of the Clarendon Avenue or shore shaft, and even here, it is believed that the shaft will safely withstand all excess pressure produced by the maximum surge.

Such systems as the above give rise to intricate surge problems and it is our custom to study them by means of models. This has proven very satisfactory as many different loadings and rejections of loads could be easily applied and the results obtained. The model is built on the principles of kinematic similitude.

A very recent and quite complicated surge problem has arisen with the new motor driven station at Harrison Street. This station is to replace not only the present Harrison Street triple expansion station, but also the motor driven 22nd Street station and the 14th Street station which is engine driven.

The tunnel system that will supply this new installation comprises the 8 feet Blue Island Avenue tunnel, to be fed from the new 16 feet Chicago Avenue tunnel, the Four-Mile tunnel and the Polk Street tunnels. The tunnels are connected by a new link built in Harrison Street which connects the Polk Street and Blue Island tunnels in Halsted Street. The total length of tunnel is 90,800 feet.

This station and the Chicago Avenue station will be the main, and at times the sole supply to the loop. It is therefore of the utmost

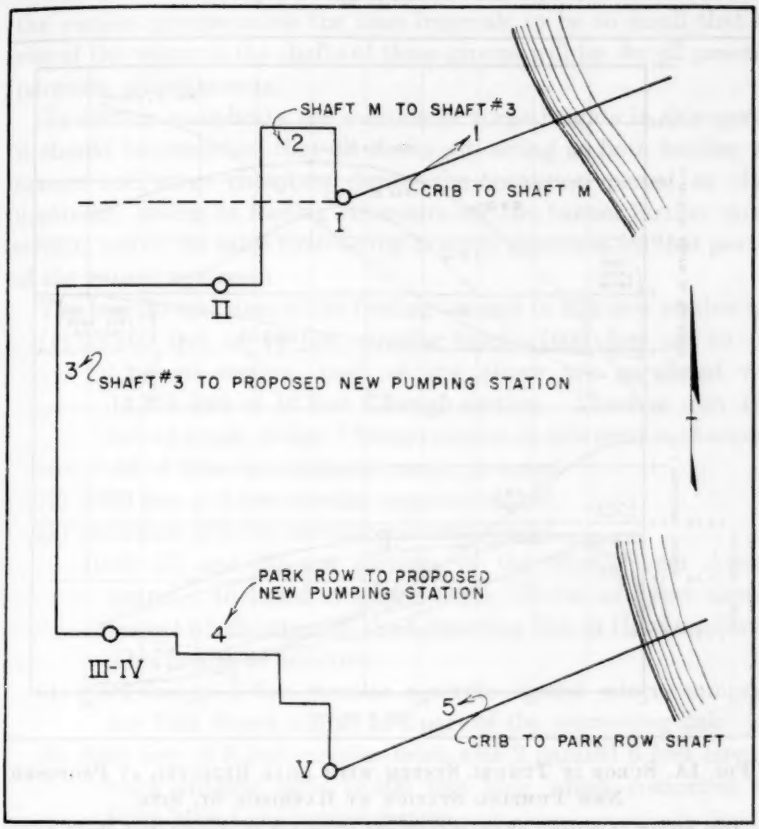

FIG. 1. SKETCH OF SIMPLIFIED TUNNEL SYSTEM (FEEDING PROPOSED NEW PUMPING STATION)

Roman numerals refer to a shaft or group of shafts. Arabic numerals refer to a section of tunnel. Shafts included in group—Group I, Shore shaft, G, D, N, H, J, K, M, #2 and River shaft—Group II, Shaft #3—Group III and IV, Shaft #4 and pumping station wet well—Group V, E. & W. 8th St. Shafts and Park Row.

importance when interruptions in electrical service occur, that the severe hydraulic disturbances be controlled.

The maximum pumpage of this new installation will be 225 m.g.d. and in the event of a complete shut-down at this rate, the kinetic

energy to be absorbed is 29,400,000 foot-pounds, of which 1,840,000 foot-pounds are delivered by the changes in velocities in the Chicago Avenue tunnel where a load of 116 m.g.d. is rejected.

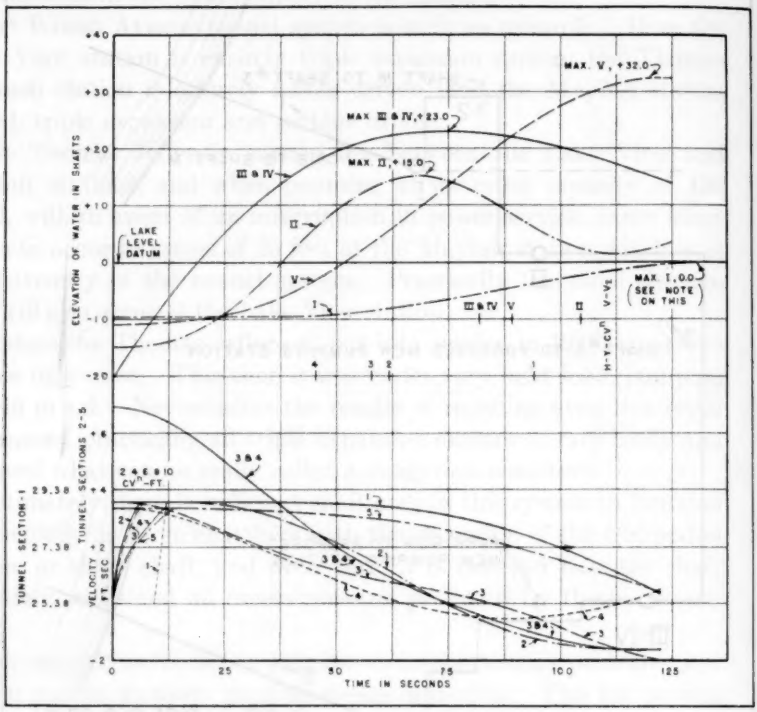

FIG. 1A. SURGE IN TUNNEL SYSTEM WITH LOAD REJECTED AT PROPOSED NEW PUMPING STATION AT HARRISON ST. SITE

Top group of curves show movement of water in designated shaft groups with a load of 225 m.g.d. rejected at the proposed new Pumping Station.

Bottom group of curves show changes in velocity in equivalent 8′ ϕ tunnel in various tunnel sections during period of Surge. Also actual friction loss in various tunnel sections corresponding to equivalent velocity in 8′ ϕ tunnel is shown.

Pivot points are shown which are used in extending the curves, each Shaft Group and Tunnel Section having a separate point.

The resulting surge heights and also the arrangement of the feeding tunnels connected to this new installation are shown in figure 1 and figure 1a.

Referring to figure 1 and figure 1a it will be noted that in solving

this problem the shafts connected to this tunnel system were grouped and used as acting simultaneously as surge chambers.

This procedure is permissible since the closeness of the shafts in the various groups cause the time intervals to be so small that the rise of the water in the shafts of these groups will be, for all practical purposes, simultaneous.

To further complicate the solution of surge heights in this system it should be remarked that all shafts are acting as both feeding reservoirs and surge chambers during the transition period as those upstream, acting as feeding reservoirs for the tunnel further downstream, are at the same time acting as surge chambers for that portion of the tunnel upstream.

The lengths and sizes of the feeding tunnels to this new station are:

(1) 13,800 feet of 10 feet circular brick, 1600 feet of 10 feet Chicago section; both of the above are paralleled with 14,174 feet of 16 feet Chicago section. There is also 1945 feet of single 16 feet Chicago section in this section of supply. All of these are concrete except as noted.

(2) 8150 feet of 8 feet circular concrete tunnel.

(3) 8950 feet of 8 feet circular concrete tunnel.

Both (2) and (3) are sections of the Blue Island Avenue tunnel. Included in section (3) is 520 feet of 7 feet circular tunnel which is part of the connecting link in Harrison Street. This link is of concrete.

(4) 8274 feet of 7 feet circular concrete tunnel which comprises the Polk Street tunnel and part of the connecting link.

(5) 8950 feet of 8 feet circular brick and 2 parallel 6 feet circular brick tunnels each 12,500 feet long which comprises the Four-Mile Lake tunnel system.

The total weight of water in these tunnels, excluding (1), which will feed other stations in addition to Harrison Street, is 144,900,000 pounds.

The shaft groups comprise the following:

I. Consists of 11 shafts in the immediate vicinity of Chicago Avenue pumping station and range in size from 10 to 17 feet in diameter. All are circular.

II. Consists of one 10 feet circular shaft.

III and IV. Consists of one 10 feet shaft and the 17 feet wet well at the station.

V. Consists of three 10 feet circular shafts on the Polk Street and Four-Mile tunnels.

The maximum surge waves that will occur with the present shaft area are 43 feet at Harrison Street pumping station and in group "V." These heights are based on the assumption that all the shafts are carried up to these elevations or from 10 to 17 feet above the existing surfaces. It should be noted that due to the large number of shafts acting at Chicago Avenue, the surge heights are of practically no consequence.

A very interesting feature in connection with this problem is shown by the velocity curves indicating that 65 to 85 seconds after the shut-down, all land tunnels are in reversed flow while both lake tunnels are flowing normal.

STEAM TURBINE CENTRIFUGAL VS. TRIPLE EXPANSION PUMPS

Many inquiries came to our office as to why the City of Chicago has decided on steam turbine driven centrifugal instead of triple expansion pumps.

As early as 1914, for reasons of expediency the City installed turbo-centrifugal pumps for reserves in several of its stations (Springfield, Central Park, Harrison Street and 14th Street), but it was not until 1921, when comparative studies were being made for the Western Avenue Station, that it was definitely established to the satisfaction of the City engineers, that turbo-centrifugal pumps had economical advantages over triple expansion plunger type pumps. At the same time it was felt that the future trend of turbo-centrifugal pump duties was upward, while the triple expansion pump duties had about reached their greatest possibilities.

The maximum size triple expansion pump that the builders were willing to build was 50 m.g.d. These pumps were to have a mechanical efficiency of 94.5 percent and a duty of 205 per 1000 pounds of steam at 200 pounds pressure and 100°F. superheat. This meant a duty of 168.2 per million B.T.U. or a thermal efficiency of 21.8 percent.

The maximum size turbo-centrifugal pump that was thought possible to use in following the load curve at this station was 60 m.g.d. These pumps were to have a duty of 173 per 1000 pounds of steam at 300 pounds pressure and 200°F. superheat. This meant a duty of 130 per million B.T.U. or a thermal efficiency of 18 percent.

The steam economy of the triples made a slightly smaller boiler plant possible and lower fuel costs.

The maximum pumping capacity of the Western Avenue pumping

station was estimated at 300 m.g.d. plus one unit for reserve, so that seven 50 m.g.d. triple expansion pumps were required and six 60 m.g.d. turbo-centrifugal pumps. The original cost of the triples was three times that of the turbo-centrifugal pumps and the total equipment costs were twice those for a turbo-centrifugal station. Some of the estimated costs made at that time are given in table 1.

To a city which each year adds 40 to 50 million gallons per day to its pumpage capacity, the change from reciprocating to centrifugal pumping equipment has meant a great financial advantage in cost of equipment and buildings. Two 60 m.g.d. turbo-centrifugal pumps

TABLE 1

Comparative costs of different types of pumps

INVESTMENT COSTS	TURBO-CENTRIFUGAL	TRIPLE EXPANSION
Land	$52,072.00	$58,748.00
Buildings	933,350.00	1,154,250.00
Equipment	1,201,400.00	2,423,858.00
Miscellaneous	18,000.00	20,000.00
Total investment	$2,204,822.00	$3,656,856.00
OPERATING COSTS		
Labor	$63,495.00	$89,437.00
Coal at $4.00 per ton	244,800.00	190,944.00
Oil, waste, etc	3,000.00	15,300.00
Repairs, and maintenance	22,624.00	40,616.00
Interest and depreciation	136,600.00	201,700.00
Total operating cost	$470,519.00	$537,997.00

were recently installed in a station within the space previously reserved for one 25 m.g.d. reciprocating pump.

LIMITED USE OF STORAGE RESERVOIRS

Another question we are frequently called upon to answer is in regard to the limited use of storage reservoirs in Chicago.

The City of Chicago has an area of 211 square miles, of which about 170 square miles lie below the 30 foot contour, (city datum lake level), the street grades varying generally from +10 to +30 feet. About 41 square miles of the city lie above the 30 foot contour rising gradually from +30 to +90 feet. One such section is found

in the extreme southwest and one in the extreme northwest part of the city, each being of limited area above +40 feet. The areas above the 40 foot contour are supplied by so-called high pressure lines from Mayfair and Roseland pumping stations.

In general, the topography of the city is such that storage would have to be elevated or if ground reservoirs were used re-pumping would be necessary; no natural elevation being sufficient to produce the required distribution pressure.

The pressures carried at present for maximum load requirement in 170 square miles do not exceed 45 pounds per square inch (curb grade at pumping stations). The pressure is reduced at night. Resulting distribution pressures are usually not less than 25 pounds. This would not be sufficient to fill elevated storage in areas at a distance from the stations, where reinforcement of pressures is desirable during the hours of maximum demand. To fill such a storage would require an independent pipe line with high head pump at the station, and to use such a storage successfully would require the isolation of the area to be supplied and the control of the services therein.

The tunnel capacity of each of the three tunnel zones is as follows:

	m.g.d.
Wilson Avenue	400
Central system, including 16 feet Chicago Avenue tunnel under construction	1,200
Southwest Lake and Land tunnel	500*
	2,100

* Present P. S. capacities.

Assuming 300 g.p.d.p.c., maximum hour requirement for a metered system, the tunnel capacity would be adequate for a city of 7,000,000 people.

NIGHT SHUT-DOWN OF PUMPING STATION WITHOUT AFFECTING WATER PRESSURE

A most interesting development resulting from a careful study of load and pressures in our distribution system has been found in connection with the operation of our newest—the Thomas Jefferson pumping station.

It supplies water to an area of about 20 square miles during the hot weather season. This requires the operation of two 50 million

gallon pumps, the peak load pumpage is at the rate of 106,000,000 m.g.d. During the Fall, Winter and Spring seasons, this station normally supplies an area of about fourteen square miles. Up to

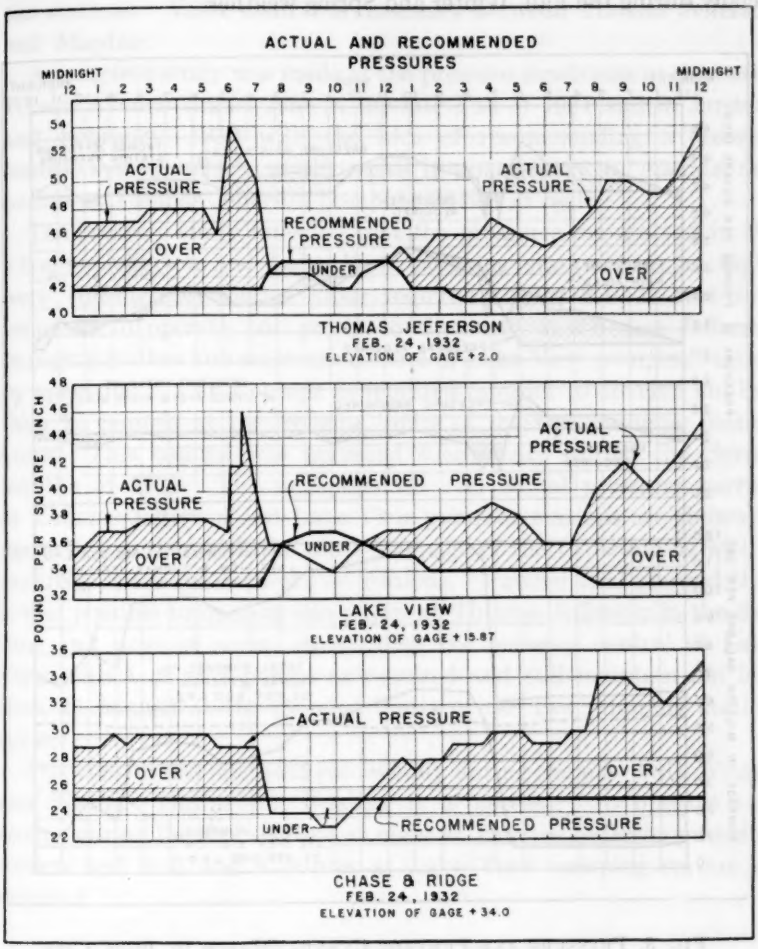

FIG. 2

March 1, 1932 two pumps were operated in the day time and one pump at night.

The section of the city supplied by this pumping station consists largely of apartment buildings and residence hotels. The amount of water pumped for industrial and commercial purposes is relatively

small. It is in a section of the city which, because of the size of the buildings used for residential purposes, is largely metered. This tends to reduce considerably the per capita pumpage rate, especially during the Fall, Winter and Spring weather.

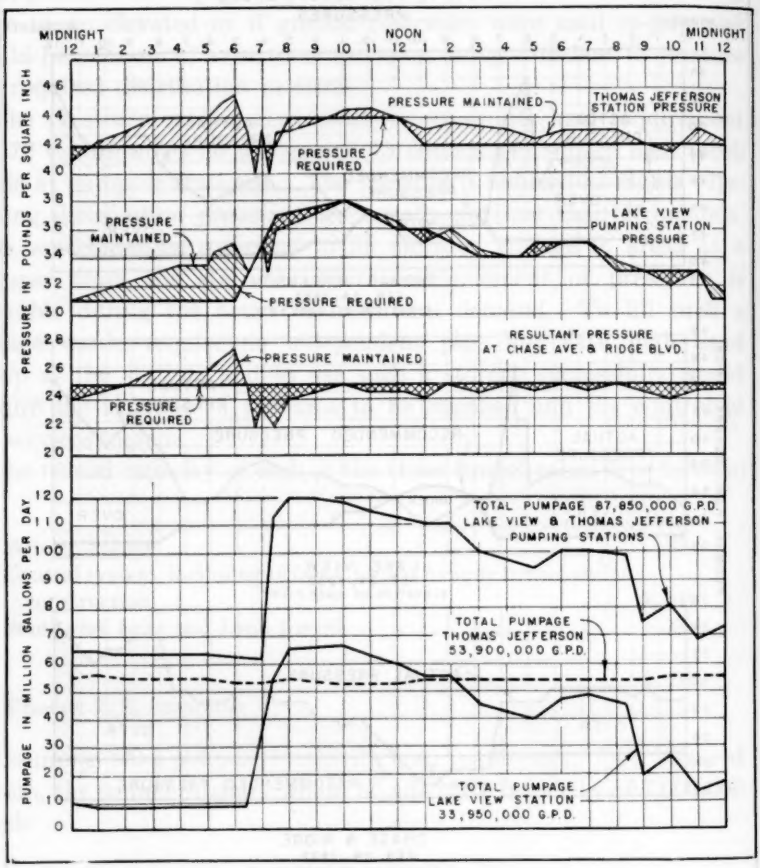
MIDNIGHT
NOON
MIDNIGHT
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
PRESSURE IN POUNDS PER SQUARE INCH
46 44 42 40 38 36 34 32 30 28 26 24 22 20
PRESSURE MAINTAINED
THOMAS JEFFERSON STATION PRESSURE
PRESSURE REQUIRED
PRESSURE MAINTAINED
LAKE VIEW PUMPING STATION PRESSURE
PRESSURE REQUIRED
RESULTANT PRESSURE AT CHASE AVE. & RIDGE BLVD.
PRESSURE MAINTAINED
PRESSURE REQUIRED
PUMPAGE IN MILLION GALLONS PER DAY
120 110 100 90 80 70 60 50 40 30 20 10 0
TOTAL PUMPAGE 87,850,000 G.P.D. LAKE VIEW & THOMAS JEFFERSON PUMPING STATIONS
TOTAL PUMPAGE THOMAS JEFFERSON 53,900,000 G.P.D.
TOTAL PUMPAGE LAKE VIEW STATION 33,950,000 G.P.D.

FIG. 3. PRESSURE AND PUMPAGE CURVES (MARCH 16, 1932), CITY OF CHICAGO

This pumping station is located about two and a half miles west of Lake View pumping station and about three miles east of Mayfair pumping station, all three stations being on the line of the Wilson Avenue tunnel.

The combined area supplied from Lake View and Thomas Jeffer-

son stations has little variation in elevations, ranging from +15 to +36 feet. Mayfair elevations range from +20 to +90 feet. No valve control is necessary between Lake View and Thomas Jefferson stations. Valve control is necessary between Thomas Jefferson and Mayfair.

A complete study was made of the pressure conditions in the entire Wilson Avenue tunnel zone in the late Fall of 1931 and in January and February, 1932 with the idea of recommending a pressure control system which would make it unnecessary to operate any pumps at Thomas Jefferson pumping station at night.

The pressure study revealed that the pressures maintained in the Thomas Jefferson and Lake View pumping station area at night were considerably higher than required. (Fig. 2.) It was first proposed to operate one pump continuously at Thomas Jefferson pumping station and maintain control of Lake View pumping station by operating 1, 2 or 3 pumps as required in order to develop not less than 25 pounds at the extreme limits of the two pumping station areas. This control was operated successfully during the Spring months of 1932. The recommended and actual pressures carried at Thomas Jefferson and Lake View pumping stations are shown in figure 3, together with the total pumpage of the two stations with a pumpage curve for each of two stations. Further trial showed that it was possible to operate one pump at Thomas Jefferson in the day time and none at night, maintaining the pressure control at Lake View with 1, 2 or 3 pumps as required and still maintain not less than 25 pounds at the extreme limits of the two pumping station areas.

This control has operated successfully during the past Fall, Winter and Spring. During hot weather it is necessary to operate two pumps during the day and one at night at Thomas Jefferson pumping station and 2, 3 and 4 pumps at Lake View pumping station as required.

EXTERNAL DAMAGE TO TUNNELS

Chicago's early land tunnels were under private property. The first two, the "Old Cross Town" and "Old Polk St." tunnels so interfered with deep foundation for buildings that, although in good physical condition, they had to be abandoned. The northwest land tunnel, through both clay and rock has given considerable cause for worry for the same reason. Owners of a large apartment building

were successful in a suit against the city in '29 and collected $25,000 damages because a tunnel shaft existed under this building. In constructing the Stevens Hotel, water from the old Polk Street tunnel caused flooding of a caisson. The Civic Opera Building, the Victor Lawson Y. M. C. A. and the Lake Shore Athletic Club required special arrangement of foundations to avoid intake tunnels. Under a ruling of the Building Commissioner of the city all engineers and architects must now obtain approval of foundation plans from the City Engineer, for buildings to be constructed over water tunnels before the building permit is issued.

Perhaps the most serious accident to a "live water" tunnel which we have experienced was on the south fork of the northwest land tunnel on October 21, 1930. A 4-foot diameter caisson being constructed by a private contractor for the Chicago & Northwestern railroad was flooded out as the workmen approached a point about 7 feet over the tunnel. After several futile attempts by the contractor to stop the leak the city engineering force took over the work to protect the tunnel, and the safety of the water supply.

A city diver after removing the lagging of the collapsed caisson found that the clay below the bottom set of lagging, about 14 feet above the tunnel, had caved in due to action of the water. This made the diver's work extremely hazardous. It was found that the hole in the brick lining of the tunnel was about 2 feet wide by 3 feet along the tunnel.

Engineering ingenuity, common sense and a brave and skillful diver finally solved the difficult problem of repairing this tunnel. By means of a steel plate curved to fit the inside diameter of the tunnel and held against it by a steel cable from a winch at the surface, a form was made. A seal was effected using quick setting cement in small salt bags, and then 15 inches of this cement was placed in and over the hole. A mixture of sand and cement was then used to make a concrete plug and the caisson refilled. It was necessary to shut down the Central Park pumping station to accomplish these results.

Even tunnels under public rights-of-way may not be secure from external damage. In April, 1932 when the 8 feet diameter Blue Island land tunnel was de-watered for the first time in over 23 years, it was found that a wooden pile had penetrated the top of the tunnel to a point within 28 inches of the invert. This pile had apparently been driven in 1919 as a part of a cluster of abutment piles for the

B. & O. railroad viaduct at 117th St. Being a crooked pile it had deflected. Fortunately the impact of the pile was so great as to shear the concrete lining of the tunnel in a clean break, which squeezed to wood pile to form a water-tight closure of the break. It was sawed off and the tunnel put into service again. No damage had been done, although the pile had served to collect some débris which had entered the tunnel.

ACCRETIONS IN CONCRETE TUNNEL

This same Blue Island Avenue tunnel was found on inspection to have, in certain sections, many internal calcium carbonate accretions. It was interesting to note that in no case did these accretions extend inward over 12 inches, although in many instances they were from 2 to 6 feet in length along the tunnel, mostly on the lower half. The average velocity in this tunnel in recent years was about 2.16 feet per second. Physical Chemist John R. Baylis who studied these accretions reports most interestingly on the cause of these formations as follows:

> There are two conditions necessary to make the formation of these accretions possible; one is that the water on the inside of the tunnel must be saturated with calcium carbonate, and the other is that there must be slow leakage from the outside of the tunnel through the concrete into the inside. It is well known that the constituents in Portland cement which give the cement its binding strength are compounds of calcium and silicate and compounds of calcium and alumina. These compounds are generally referred to as being tri- or dicalcium silicates and tricalcium aluminate. Such compounds when submerged in water will give up calcium hydroxide to the extent of making the water saturated with this compound, providing there is a large amount of concrete for the amount of water. When water seeps through concrete it dissolves the calcium from the concrete and at first will come through the concrete practically saturated with calcium carbonate. It may decrease materially as the flow continues and more of the calcium is washed away. When all of the calcium has been washed away there is no strength left to the concrete.
>
> What happened in the Blue Island Tunnel where the accretions formed was, that there was a slow leak which allowed the water to take up quite a large amount of calcium hydroxide in passing through the concrete. When this solution reached the inside of the tunnel it came in contact with water saturated with calcium bicarbonate. The lime water converted the calcium bicarbonate to calcium carbonate and formed a precipitate of this substance. Some of the calcium carbonate precipitated on the walls of the tunnel around where the seepage was occurring. The precipitate of calcium carbonate was porous and offered little or no resistance to the pressure of the seepage water. As a result the accumulation of precipitated calcium carbonate kept increasing in size.

This kept continuing until the accretions reached fairly large size or until they reached a size where the flow of the water prevented them from building much larger.

Examination of the water on the inside of one of the accretions showed that it contained about 500 p.p.m. of calcium hydroxide. This is nearly one-third the saturation point of calcium hydroxide. It is likely that some of the accretions contained water with a higher concentration of calcium hydroxide and others contained a much lower concentration, due to a large amount of the calcium being dissolved from the concrete. There is the probability that in some places the accretions stopped growing, due to the fact that all of the calcium around the channel through which the leakage passed had been washed away.

ROCK VS. CLAY TUNNELS

Chicago's early tunnels were dug through clay. They were 5 and 7 feet in diameter, lined in brick. The more recent tunnels—Southwest Land and Lake, Wilson Avenue, Western Avenue and the new Chicago Avenue tunnel are all through rock and lined with concrete. In view of the recent developments in mechanical equipment in Chicago for rock tunnelling, it is now equally as cheap to construct tunnels in rock as it would be to construct them through clay, should the air and shield methods be followed. The newer mechanical equipments referred to are the mechanical mucking and stone loading equipment, the mechanical cement mixing and placing units and the new loading and unloading equipment all developed by engineers in the Construction Division. As evidence of the efficiency of rock tunnelling in Chicago, unit costs of $175.00 per foot for 16 feet diameter tunnel are now being met on the Chicago Avenue tunnel now under construction. For dependability during construction and freedom from foundation interferences later the rock tunnels are of course much superior to the clay tunnels.

CHLORINE ABSORPTION

One of the most serious conditions pertaining to the quality of Chicago's water supply is the sudden and often high absorption of chlorine applied for public health protection in the suction wells at the various pumping stations. This absorption at times is traceable to industrial wastes, especially those discharged from oil refineries and by-product coke. When the water is polluted by sewage and other organic wastes the absorption is also heavy. Frequently the sewage and industrial pollution occurs simultaneously. Sudden and heavy absorption of chlorine is usually a condition developing from a

spill or batch disposal of industrial wastes and constitutes a very dangerous condition making it necessary always to be on the alert for emergencies of this character. This condition is especially prevalent on the south side where the waters are polluted at times quite heavily by sewage and industrial wastes from the Calumet region of Indiana.

Chlorine absorption is also experienced when the lake waters become turbid and at periods during the Spring and Fall when the difference in temperature of the water at the surface and bottom of the lake approach each other. At such times a wind condition may cause a disturbance in the equilibrium of the water sending the surface water down and the bottom water up and resulting in a sudden change in the chlorine absorption property of the water. During the eight years 1925 to 1932 inclusive there were 155 instances of sudden and abnormal absorption of chlorine in the city water.

PERIODS OF WEAK FLOCCULATION

In connection with the research work on chemical coagulation of Lake Michigan water, John R. Baylis and his associates at the Experimental Filtration plant have observed a condition of weak flocculation which may have profound effect on the design of Chicago's first filtration plant.

For waters which contain an abundance of microörganisms over fairly long periods it is desirable to use fairly coarse sand in filter beds. The sand, however, must not be so coarse that it will not filter the water perfectly clear at all times. The Lake Michigan water at Chicago seems to go from one extreme to another. With sand of 0.5 mm. diameter for the 10 percent size it is not possible to obtain filter runs within the bounds of practical operation of a large filter plant more than 50 percent of the time, unless the water is treated in some special manner to lengthen the filter runs. If the water was uniformly of this character, most of the trouble could be overcome by the use of coarser sand.

It was found in the course of our experiments that there were periods of weak flocculation in which sand of 0.5 mm. diameter would not filter out all of the coagulated matter. There was one period of weak flocculation which lasted from about December 1, 1929 to March 1, 1930. Filter beds constructed of sand used quite extensively in this section of the country passed coagulated matter before the loss of head reached 2 feet and before the filters had run 18

hours. There was another period of weak flocculation in March, 1931. This period lasted only about two weeks. If two weeks was the maximum limit of such periods, it is probable that not much trouble would result by some of the coagulated matter passing through the beds. Two and one-half months, however, is entirely too long and is a condition which cannot be ignored in the design of a filtration plant to handle the Lake Michigan water at Chicago.

Experiments are under way to see if there is any way of strengthening the coagulation during such periods. If such a treatment could be found which cost as much as $10.00 to $15.00 per million gallons during the periods of weak flocculation, it is believed that this would be much cheaper than designing the plant to take care of such conditions without special treatment. It so happens in our experiments that the weak flocculation is the limiting factor in the design of the plant. The periods have not occurred often enough for us to give the study to it we should like, but we are hopeful of finding means of handling such water satisfactorily with a plant designed to handle average conditions in the lake water. The addition of fibrous material to the water will materially strengthen flocculation, and the main problem now is to find a satisfactory material which can be added at a reasonable cost.

PECULIARITIES OF CONSUMER DEMANDS

The large metered consumers in Chicago have many and varied requirements which must be considered in operating pumping stations and distribution mains.

A thorough research has been carried on by the Meter Testing and Control section of the Water Pipe, Extension Division to determine the characteristics of all large consumers within the city and of those outside the limits receiving water from the city.

The large metered areas are: The Loop district, the Stock Yards and packing town, the large residence hotels of the north and south shore districts, various industrial districts, such as the Central Manufacturing district, the Kenwood Manufacturing district, the Clearing Industrial district (which is outside the limits), all laundries, tanneries, steel producing plants, railroads, large flat buildings, cemeteries, large garages, all outside limits, consumers and many other consumers, domestic, industrial and commercial.

The characteristic curves, made by attaching a rate recorder to the meter controlling each service, reveals many varying conditions

in the rates at which consumption is taken, the high hour requirement varying in time for various users.

For domestic consumers, large and small, the high hour requirement is reached at 8:00 p.m., hot dry weather. For ordinary weather there are two high hour periods, one about 7:00 a.m., the other about

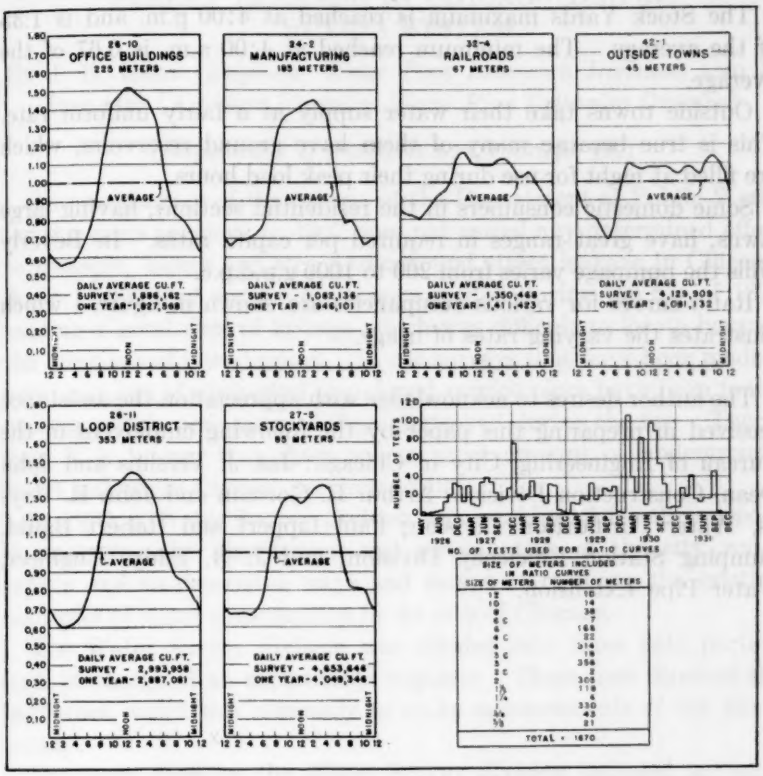

FIG. 4. RATIO CURVES (COMPILED IN 1931), CITY OF CHICAGO

7:00 p.m. The amount of water taken per capita increases as the number of flats in a building increase in number.

The Loop district maximum is reached at the noon hour, the ratio of the peak to the average being 1.45 and the minimum to the average 0.60 (353 meters). The maximum rate for manufacturing plants (185 meters) occurs at 2:00 p.m., the ratio of maximum to average being 1.45 and the ratio of minimum to average being 0.68.

Steel plants use water day and night, the maximum rate occurs in the day time and is 1.25 of the average.

Railroads use water throughout the twenty-four hour period at a fairly uniform rate. Their maximum (67 meters) occurs at 10:00 a.m. and is but 1.15 of the average, while the minimum occurs at 2:00 a.m. and is 0.8 of the average.

The Stock Yards maximum is reached at 4:00 p.m. and is 1.35 of the average. The minimum reached at 4:00 a.m. is 0.67 of the average.

Outside towns take their water supply at a fairly uniform rate. This is true because many of them have ground reservoirs, which are filled at night for use during their peak load hours.

Some domestic consumers in the residential sections, having large lawns, have great ranges in required per capita rates. In Beverly Hills the pumpage varies from 200 to 1000 g.p.d.p.c.

Ratio curves for various occupancies are shown in figure 4 which illustrates the varying rates of usage.

The author desires to acknowledge with appreciation the assistance received in preparing this paper by the following employees in the Bureau of Engineering, City of Chicago: Jas. J. Versluis and John Dean, Construction Division; Arthur E. Gorman and John R. Baylis, Water Purification Division; Paul Lippert and Robert Bauld, Pumping Station Efficiency Division; and J. B. Eddy, Engineer, Water Pipe Extension.

LOCATING AND ELIMINATING UNDERGROUND STREET LEAKAGE IN CHICAGO DISTRIBUTION SYSTEM

By J. B. Eddy (*Engineer, Water Pipe Extension Division*) and B. Phillips (*Assistant Engineer, Water Pipe Extension Division*)

(*Department of Public Works, Chicago, Ill.*)

An examination of the reports of the Department of Public Works for the years previous to 1907 does not reveal any determined effort to measure, locate and stop underground street leakage in Chicago. Some 15,000 lead service pipes were melted during the fire of 1871 causing a great deal of leakage which was difficult to locate because the records had been burned. In the surveys that have been made a great number of uncharted abandoned service pipes have been found leaking, which were some of those destroyed during the fire. Therefore, it is known that there was a great amount of underground street leakage in Chicago previous to 1907.

In 1907, a Water Survey division was established for the purpose of analyzing the distribution and consumption of the city water supply and to determine ways and means of reducing the existing high rate of water consumption in the city of Chicago.

The Water Survey division was divided into three field parties, each in charge of an experienced engineer. These men directed the field work which was necessary to make measurements of the water supply.

The work done by the Water Survey division included not only the reduction of plumbing leakage and willful waste, but also the work of collecting data showing the condition of the underground pipe lines.

Velocity measuring instruments, water meters, aquaphones, rods and other devices were used in detecting underground street leakage and plumbing waste. The method used was as follows:

Districts ranging from 70 to 360 acres were selected according to the character of the water consumption. When the area to be surveyed had been defined, the valves along the boundary of the dis-

trict were closed and a water measuring instrument was installed on the supply main feeding the district. A continuous record was made for a period of about seven days. From this test the average daily consumption of the district was determined, and also the rate of consumption during the night time when the use of water was at a minimum.

When the minimum night rate was high a second test or "sub-division" was made to localize the flow. The sub-division showed whether excessive usage was confined to one locality, or scattered over the entire district, thereby indicating the sections which should be given intensive inspection for leakage and waste and which were acceptable without further attention.

The results of the work of the Water Survey division showed that the underground leakage in the older portion of the city was serious.

The annual reports of the Department of Public Works from 1907 to 1912 show that the Water Survey division made many recommendations to stop underground street leakage. A great amount was stopped by overhauling old mains, cutting off or replacing obsolete mains, cutting off at the main abandoned service stubs found leaking, and shutting off a number of blow-off branches which were found open and discharging water into the sewers. The annual reports of the Department of Public Works show that in 1907, 1,645-000 g.p.d. of underground street leakage were stopped and in 1912, 8,456,000 g.p.d. The appropriations for the Water Survey work from 1907 to 1912 included money for engineering and inspection only. Money for corrective measures to stop underground leakage could only be drawn from the appropriations of the Water Pipe Extension Division, which arrangement was not entirely satisfactory. No appropriation was made for Water Survey work for 1913 and consequently the division was disbanded.

UNDERGROUND STREET LEAKAGE 1910 TO 1915 INCLUSIVE

Streets having water mains which were up for paving were tested during minimum night rate flows. These tests were made between the hours of midnight and 4 a.m. A corporation cock was inserted in the main in a valve basin and a rod meter installed, and a valve at the opposite end of the section of the main closed. No service pipes were closed, test being known as an open test. "U tube" readings were made every minute for periods of 10 minutes to a half hour. By this method it was determined whether the amount of

water flowing into a section was sufficient to justify an investigation of the underground condition of the main and service pipes. If the amount of water flowing into the section was high, the usual method of stopping the underground street leakage was to shut off all abandoned service pipe stubs at the main by closing the corporation cock. Usually all pipe joints and service taps were uncovered. This method involved considerable expense and required many street openings.

UNDERGROUND STREET LEAKAGE IN CONNECTION WITH STREET PAVING—1916 TO 1932

In 1916 three engineering parties were organized for the purpose of inspecting and testing mains and service pipes up to the curb stop-cock to measure, locate and stop leaks therein wherever streets were about to be paved. These engineering parties consist of a junior engineer, a rodman and two laborers, with a truck. Recommendations for all changes and repairs to eliminate leakage made by the district engineers are embodied in orders, issued to the district forces. This work has been carried on with great regularity and efficiency from 1916 to date and has been of great value as it has placed the distribution system in first class condition in every street where a pavement has been laid.

Street improvement tests have been made on 1057.64 miles of mains from 1916 to 1932 inclusive. This is 28.49 per cent of the total mileage in service, at end of 1932. Underground leakage of 17,432,261 g.p.d. has been measured in these 1057.64 miles of pipe. 6,766,885 g.p.d. leakage was found and stopped in connection with special tests other than street improvement tests in addition to the regular work, making a total of 24,199,146 g.p.d. of which 22,960,879 g.p.d. were stopped.

Of a total of 1456.68 miles of mains tested for underground street leakage from 1916 to May 31,1933, 752.88 miles were found tight on first test which is 51.68 percent of the total miles of pipe tested.

During the past 25 years 1791 miles of mains were added to the distribution system, and 197 miles of mains abandoned. The mains laid during these years have all been tested under a static pressure of 100 pounds per square inch when laid and should be in good condition as regards leakage. The mains abandoned were a part of the original system and were obsolete, poorly located, inaccessible or had enormous underground leakage.

The method of testing mains for underground leakage is as follows: A section of the main about two blocks long is isolated by closing off all of the service pipes at the stop-cock at the curb and by closing gate valves at the ends of the two block section. The leakage, if any, is measured into the section through a 1- or 2-inch water meter by tapping the main and by by-passing one of the valves at the end of the section. In case the leakage is too large to be measured by the 2-inch meter the by-passed valve is opened and a velocity measuring instrument is inserted in the main. In shutting off the valves and the stop-cocks, a sounding rod and aquaphone are used on each to determine if the sound of leaking water can be detected. If measurable leakage is shown to exist a number of methods are used to locate the same.

SPECIAL TESTS FOR UNDERGROUND LEAKAGE BY STREET IMPROVEMENT PARTIES

From 1916 to 1932 special tests for underground street leakage have been made by the street improvement parties. Whenever a depression or hole in the pavement was observed indicating leakage or if complaints were received of noise in the plumbing, or water was reported in manholes or conduits of utility companies or considerable water was found flowing away on the surface, special tests were made to measure, locate and stop the underground leakage. 6,766,885 g.p.d. of underground leakage have been stopped as a result of these tests.

UNDERGROUND LEAKAGE WORK IN CONNECTION WITH METERING, 1926, 1927 AND 1928

An Underground Leakage section was organized in the year 1926 following the passage of the Universal Metering Ordinance to carry on the engineering work in connection with the stopping of leakage in the water system during the metering. The personnel consisted of an assistant engineer in charge, one assistant engineer in charge of field operations, and three field parties, each party being made up of one junior engineer, two rodmen and two laborers, with a truck.

The work of this section was carried on in 1926 and 1927 and in the first six months of 1928 in fourteen square miles in the southeastern part of the city. Meters were set in this area before the Underground Leakage section had completed its work. During the last six months of 1928, the parties were transferred to the older sections of the city, and at the end of the year disbanded.

The Hegewisch Section of the city had been placed under meter control in the Fall of 1920, but on account of additional building operations it required about 200 meters to again place it under meter control early in 1926. Before this section was metered the total average daily per capita rate was 455 gallons and after this section had been under meter control for approximately one year the total daily per capita rate was 97 gallons. In this particular section the underground leakage previous to metering was 8 gallons per day per capita. This was reduced to 2 g.p.d.p.c. It is to be noted that the plumbing leakage and willful waste were reduced by 354 g.p.d.p.c.

The total flow into the district bounded by 71st St. on the north, Lake Michigan and Indiana State Line on the east, City Limits on the south and Yates Av. on the west previous to metering was at the rate of 28,100,000 g.p.d. This figure was arrived at from surveys made from 1920 to 1924. A survey made in October, 1927 after metering had been completed showed that the total average daily flow was at the rate of 11,260,000 gallons. The total saving amounted to 16,840,000 g.p.d. of which 12,051,800 g.p.d. were chargeable to plumbing leakage and willful waste and 4,788,199 g.p.d. to underground street leakage or 17 percent of the total flow into the district.

The underground street leakage was found throughout the entire section in which meters were installed, practically every street having some measurable leakage. A total of 6,586,172 g.p.d. of underground leakage was stopped in 173 miles of pipe including service pipes, hydrants and valves during the years 1926, 1927 and 1928.

The method of making the tests of mains for underground street leakage from 1926 to 1928 was similar to that used in connection with street paving work, except that instead of operating the stopcock at the curb the service was shut off at the house meter by means of a wheel valve. Where the mains were at extreme depths and where the leaks were water bound, which was common in the southeastern part of the city, the "dye method" was used to locate the leaks.

SPECIAL REHABILITATION WORK, 1931, 1932 AND 1933

In the latter part of 1931 special rehabilitation parties were organized to stop underground street leakage. Each party consisted of a junior engineer, one plumber and two laborers with a truck. During 1931 the total amount of underground leakage measured was 789,810 g.p.d. of which 504,967 g.p.d. were stopped, in 32.37 miles of mains including service pipes, hydrants and valves. In the older

sections of the city west of the Loop the leakage measured was 204,600 g.p.d. per mile of pipe tested and in the south part of the city where the mains are comparatively new, the leakage measured was 5,109 g.p.d. per mile of pipe.

The special rehabilitation work which was organized in 1931 was continued in 1932 and additional field parties were added. Five of the eight field parties engaged in this work operated in the old sections of the city west of the Loop district where the underground street leakage was known to be high. In this section of the city the amount of underground leakage measured during 1932 was 14,334,250 g.p.d. of which 11,501,400 g.p.d. were stopped in 53.03 miles of mains, including service pipes, hydrants and valves. Unused and uncharted service pipes accounted for a large part of the leakage found. The unused services formerly supplied premises and were not shut off at the main when the buildings were wrecked; the water was found discharging into the sewer through the house drain. The other field parties operating in the north and south sections of the city where the mains were laid at more recent dates, measured in 1932, 5,956,670 g.p.d. of underground leakage, of which 5,248,252 g.p.d. were stopped in 92.23 miles of mains, including service pipes, hydrants and valves. The leakage measured per mile of pipe not including special tests was 64,585 g.p.d.

Special rehabilitation parties in 1931 and 1932 and to May 31, 1933 measured 27,082,912 g.p.d. and stopped 23,408,566 g.p.d. of underground street leakage in 226.04 miles of pipe. In the southern part of the city subdivision tests were made on nine miles of mains and aquaphone surveys on 100 miles of mains and the leakage found to be negligible.

A number of methods are used in locating the leakage. Listening with an aquaphone upon rods in contact with the main is used with great success. Where the mains and services are deep or leaks are water bound, which is quite general in older sections of the city, the locating of underground leaks is almost impossible by ordinary methods.

A method of testing to determine the location of leaks where the mains are at extreme depths and where the leaks are water bound is known as the "dye method." A full description of the method of locating underground leaks by the "dye method" appeared in THE JOURNAL of Jan. 1928, Vol. 19, Bk No. 1. Pages 1 to 35 inc.

At the present time listening surveys are being conducted in the

south part of the city. These surveys consist in listening with an aquaphone on all hydrants, valves and on at least one service pipe at the roundway stop-cock every one hundred feet. If a leak is heard on the service pipe, the roundway stop-cock is closed and opened to determine whether the leak is between the main and the curb cock or between the curb cock and the premises.

SUMMARY OF RESULTS

The combined results of the work of the street improvement and special rehabilitation parties during the period from 1916 to May 31, 1933, inclusive, show that, in 1565.68 miles of mains surveyed, a total of 57,868,230 g.p.d. of underground street leakage have been measured, or an average of 36,960 g.p.d. per mile of pipe. Applying an average of 36,960 g.p.d. per mile of pipe surveyed during the period from January 1, 1916 to May 31, 1933 to the 2146.56 miles of pipe in the system unsurveyed (3712.24 less 1565.68) a leakage of 79,336,858 g.p.d. in the pipe which has not been surveyed during this period is indicated. Applying an average of 6,000 g.p.d. per mile to 1565.68 miles of pipe (which experience has indicated has developed in this mileage since it was surveyed) a leakage of 9,394,000 g.p.d. is indicated.

The total amount of leakage in the present distribution system, therefore, may be estimated at 88,730,858 g.p.d. or an average estimated leakage of 23,902 g.p.d. per mile of pipe in service. The average daily pumpage for the city and suburbs in 1932 was 1,010,000,000 g.p.d. Therefore, the above figures indicate that the underground street leakage in the distribution system, including service pipes up to the stop-cock at the curb may be estimated to be approximately 8.8 percent of the average daily pumpage.

DISCUSSION

FRED B. NELSON (Civil Engineer, Department of Water Supply, Gas and Electricity, New York, N. Y.): Underground waste as to amount and methods of control is a factor in water supply and maintenance that never has been and never can be standardized or codified for practice in all cities. In fact, there are probably no two cities in which the subsurface conditions, adequacy of supply, cost and method of distribution, etc., are sufficiently similar to warrant application of like methods.

The co-authors of this paper are to be congratulated not only for

an interesting presentation of the Chicago problem and its solution, but upon their years of successful work and experience along those lines which is back of that paper.

As I understand from the present and previous accounts, the following are some of the interesting features of Chicago underground waste that are in more or less sharp contrast with the condition to which I have had fairly thorough introduction in New York City. Please bear in mind that I am not assuming authority in the mentioning of these factors relative to Chicago, but rather presenting them for the purpose of raising questions for discussion and to receive pointers from the men who know. To learn from the discussion that the assumptions or conclusions are wrong will be fully as helpful as a "Yes."

In a large portion of the area of the Chicago system the mains were laid below the original low surface elevation; in many cases in marsh land which was afterward filled in, leaving the mains at a considerable depth and either submerged in the ground water or submerged when leakage of any magnitude raises that ground water level. This circumstance quite largely defeats the use of the aquaphone, which in New York City is the simple, but principal, every day instrument used in the detection and location of subsurface leaks.

Quite generally I would assume that soil conditions in Chicago are such that leaks of serious proportion will appear at the surface or other observable points and be taken care of in the regular maintenance work. The Boroughs of Manhattan and The Bronx, comprising 40 per cent of the total mileage of mains in New York City, present in marked contrast a condition of rock filled streets and trenches such that the appearance of a leak at the surface is a rare exception to the rule and its noise is seldom muffled by submergence.

In years past the Chicago policy on water main extensions was to install the service pipe to the curb line on the frontage of individual lots to avoid subsequent opening of the pavement. Undoubtedly the aim of this policy was good and it may have had other virtues, but I will venture the opinion that it did not originate with an experienced water waste man. Abandoned service pipes in New York City are probably the most troublesome source of leaks with which we have to deal. If the leak is distant from the street main the vibration reaches the main too weak to be picked up, especially without knowledge of the service location, and the larger the leak or the more nearly it approaches the service capacity the lower the

vibration or sound. Frequently soundings to locate the high point of water in the ground have had to be utilized to get the location of the leak, and the pipe locator used if necessary to find the service connection to the main.

Under the Chicago conditions the measurement of the leakage with a hose and meter to supply a shut off of main with the connecting service pipes closed off at the curb is an effective method of detecting leakage. It will be interesting to know in that connection just what difficulties were encountered by way of imperfect curb boxes and line valves together with back flow from corner houses and other buildings that may have connections to more than one main and imperfect check valves on those connections. These have been some of the serious difficulties in the small amount of hose and meter work that has been done in New York City.

Based upon these tests and other surveys, the underground leakage from mains as compared with portions of New York City is slight, I believe estimated at around 10 percent. It seems quite possible that the small amount of this factor in the Chicago water consumption might be due to a slightly yielding soil foundation for the water mains such as may permit a slightly varying but not abrupt settlement of the pipe and without contact with unyielding rock or solid structures. This evidently small amount of underground leakage leaves fixture leakage and pump slippage very largely to account for approximately 285 gallons per capita as compared with New York's 135.

In contrast with New York, Chicago's available supply is not limited and does not require to keep pace with growing demands an extensive watershed development, the postponement of which in New York City can be shown to pay handsomely for conservation effected by curtailment of waste. On the other hand, the cost of pumping in Chicago must fully warrant very considerable expenditures to accomplish a resulting and immediate decrease in that continuous expense. For twenty years past we have computed our cost per million gallons saved based upon what we find to be a very conservative estimate that without the water waste work the leaks located and stopped would have continued for an average of two years. Verifying this assumption, we have had many cases of service pipe leaks in which there was quite positive evidence that they had been running for ten years or more. We have located breaks in small mains that had been running one-half to a million gallons

measured discharge evidently for more than one year, and in one or two cases quite positive evidence that they had been running for a longer time. On the aquaphone surveys made in 1931 and 1932, by which means undoubtedly an accumulated leakage of several years was stopped, this cost per million gallons saved has been close to $2.50.

The aquaphone method, which is suitable and very effective under New York conditions, can be used there to cover a large territory in a short time with a resulting great saving out of such an accumulation. With a very limited possible use of the aquaphone under Chicago conditions the more difficult procedure would have to be resorted to, and undoubtedly the cost per million gallons figured on that same basis would be considerably in excess of that in New York City.

In the Memphis convention of 1932 an account was given of the results accomplished in New York City during 1931 utilizing a special additional force on a systematic aquaphone survey of the Boroughs of Manhattan and The Bronx to locate and stop the largest detectable leaks and secure rapid conservation on account of threatened shortage. The saving accomplished during 1931 by the special force amounted to 26 million gallons daily. During 1932 we have covered the greater portion of the same area, repeating the aquaphone test on valves and hydrants and in addition aquaphoning the individual service pipes to locate the smaller leaks and those between valves and hydrants which could have been overlooked on the first survey. This second survey has resulted in the stopping in the same areas, of leaks greater in number, but smaller in average size, so that during 1932 a leakage was stopped totaling 24,800,000 gallons per day. No doubt the experience of the new force on the first survey accounts to a great extent for their accomplishment on the second, in which they were dealing with smaller leaks.

Thus far this year the rate at which leakage is being stopped corresponded closely with the rates for 1931 and 1932 until a few recently located large leaks, including a broken 6 inch with break edges separated a half inch and discharging two million gallons daily has put the curve above those of the two preceding years.

With the rate at which leakage is stopped being maintained by the same force in the second survey of the same areas, we are apparently still working on the "blind" leaks that accumulated in the years preceding the systematic survey, and are not yet in position to say what period between systematic surveys will be economical for the

future control. Experience suggests, however, that the present force and organization is gaining on the accumulation and is probably about right for economical control of underground waste after that accumulation is cleaned up.

The force on survey work starting with 1931 includes an assistant engineer, three engineering assistants and a foreman, supervising four field parties, each consisting of three laborers, one caulker and an auto engineman, with truck and equipment.

The original water waste force, consisting of four field parties similarly organized and supervised, is continued and has been found to be adequate only to take care of location of leaks causing complaint after reasonable effort by the regular repair companies has not succeeded.

SPECIAL LOW-HEAT CEMENT FOR MASS CONCRETE DAMS

By Samuel B. Morris

(*Chief Engineer and General Manager, Water Department, Pasadena, Calif.*)

The construction of Pine Canyon Dam for the City of Pasadena in twenty months from date of contract to time of completion has presented special problems in mass concrete. Contract was entered into April 25, 1932 and completion of the dam is required by December 31, 1933. The dam is a gravity type structure 245 feet above streambed, 328 feet in height above lowest foundation, 277 feet thick at its base and 20 feet at its crest. It is 750 feet in length at the crest, and contains 436,000 cubic yards of mass concrete.

A number of dams of about this magnitude have been constructed in the past. All of the older dams have been constructed very much more slowly than the 20 month construction schedule required for Pine Canyon Dam. Some of the most recent high dams have approached such a fast pouring rate.

Close inspection of a large number of concrete dams showed clearly that the older dams were in general cracked much less than the newer ones in spite of the advance of concrete technology and control in effect in recent years. We do not have a very good record of the character of cement used in these older structures. In general, we know that it was coarser ground, of not such high early strength, and that the concrete was placed much dryer than in the recent dams where concrete chutes have been used.

Most of the recent progress in development and manufacture of cement has been to produce a cement of high early strength for structural and highway purposes where comparatively thin sections of concrete have been the principal market. True, a considerable number of large concrete dams have been built, but the total quantity of cement used in their construction has been a small percentage of the total cement produced.

In large gravity-section concrete dams there is no requirement of

early strength of cement. The maximum compressive stresses with dam fully loaded are relatively small. In the case of Pine Canyon Dam, the maximum inclined stress at the toe was 325 foot dam section and water surface at top of parapet wall is only 351 pounds per square inch. Maximum stress during earthquake with acceleration of 1/10 gravity and maximum storage level five feet below crest of dam is but 433 pounds per square inch.

As the base of the dam is poured first there is no possibility of even these maximum stresses occurring earlier than one year after the concrete is placed. The concrete at that time will have a strength easily ten times the maximum compressive stress to which it will ever be subjected. Therefore, securing concrete of high early strength is not necessary.

The principal requirements of mass concrete for gravity concrete dam construction are, low heat of hardening, constancy of volume, impermeability, high density and durability.

The heat generated by the chemical reaction of the cement during the setting or hardening process causes the mass concrete to rise in temperature and to expand in volume until the radiation from the surface is as great as the rate of generation of heat in the concrete, after which the concrete falls in temperature.

Large concrete dams require the passing of years before the interior of the dam reaches the mean annual temperature. The shrinkage of the concrete with the base fixed and tied to solid rock foundation causes tensile stresses in the concrete and frequently cracks to form in the mass of the dam.

Contraction joints can be provided at 50 foot intervals along the axis of the dam to prevent cracking perpendicular to the faces or axes of the dam. With a dam as thick as 277 feet at its base there is further tendency for the dam to crack in a direction parallel to its axis. It is not so simple a matter to provide contraction joints parallel to the axis of the dam, as such division of the dam into slices parallel to the axis would seriously interfere with the stability of the dam.

Reduction of heat in the dam and resultant tensile stresses in the concrete as the dam cools can be accomplished by reducing the amount of cement used, by such methods as using a cement admixture such as finely ground silica used by the Reclamation Service in construction of Arrowrock and Elephant Butte Dams. Or a similar result may be obtained by use of a large percentage of plums. Experience at Arrowrock where serious sloughing of the downstream

face has occurred, does not encourage any great use of cement admixtures. The use of plums in the concrete is uneconomic. In either of these methods of reducing internal heat the result is accomplished by a reduction in the amount of cement used per cubic yard of mass concrete in place. The use of a coarse ground cement to secure low heat generation is the equivalent of using less cement as the cement coarser than 200 mesh has so little effective surface that it has little cementing quality.

The problem has therefore been to secure a cement of substantially less than normal heat of hardening, and of sufficient strength, constancy of volume, and durability to meet the requirements.

Fortunately much research upon this problem had previously been carried on by the Riverside Cement Company in California[1] and more recently by the University of California for the U. S. Bureau of reclamation in the Hoover Dam studies. However, the specifications prepared a year ago for the purchase of 470,000 barrels of cement for Pine Canyon Dam, are believed to be the first specifications ever issued in which a large quantity of cement was purchased with a provision specifically limiting the heat of hydration at 7 and 28 days.

SPECIFICATIONS FOR LOW HEAT VALUE CEMENT FOR PINE CANYON DAM

In the preparation of these specifications No. S.G. 3 issued July 12, 1932 for the purchase of 470,000 barrels of low heat value cement, it was our desire to depart as little as possible from the requirements of, and methods of test for, Portland Cement in general use as manufactured to meet the requirements of Standard Specifications for Portland Cement (Serial Designation C9–30) of the American Society for Testing Materials. In fact the Specifications No. S.G. 3 distinctly provide for a true Portland Cement and no intergrinding of finely ground silica or other materials with the cement clinker is permitted.

Owing to the high heat evolved by tricalcium aluminate and its relatively large contribution to volume change, this element in the cement was limited to not to exceed 6 per cent by weight when computed by the method of Bogue.[2]

[1] Effect of Composition of Portland Cement on Heat Evolved during Hardening by Woods, Steinour and Starke, Riverside Cement Company, Industrial and Engineering Chemistry, Nov. 1932.

[2] Analytical Edition, Industrial and Engineering Chemistry, 1: 4, page 192, October 15, 1929.

In order to insure against the formation of dicalcium ferrite which research by Bogue and others indicates will not form if tricalcium aluminate is present, Specifications No. S.G. 3 were later modified so as to provide also a lower limit for tricalcium aluminate which the specifications now provide shall be not less than 1 percent nor more than 6 percent.

The residue on a standard No. 200 sieve was originally limited to not to exceed 15 percent nor less than 2 percent by weight. During the early placing operations at Pine Canyon Dam where a very dry concrete under close cement-water ratio control is compacted by use of both internal and platform-type vibrators, it was found much more difficult to place the coarser ground cements varying from 10 to 15 percent retention on a No. 200 mesh sieve. By mutual consent of the cement companies, the specifications have been changed to provide a residue on a Standard No. 200 mesh sieve of not to exceed 8 percent nor less than 2 percent by weight.

The desirability of specifying fineness of cement by specific surface rather than by sieve analysis was recognized, but abandoned on account of the cost of tests and test equipment, and the unfamiliarity of most of the cement mills with their ability to control the specific surface between desirable specified limits.

No requirement was placed upon the tensile strength of standard mortar briquettes, but rather compressive tests were substituted as follows:

The average compressive strength in pounds per square inch of not less than three cylindrical test pieces 2 inches in diameter and 4 inches in length, composed of mortar containing one part cement and three parts standard Ottawa sand, by weight, when tested in accordance with the tentative standards for compressive strength of portland cement mortars (Serial Designation C9–16T) of the American Society for Testing Materials, shall be equal to or higher than 800 pounds per square inch at 7 days and 2000 pounds per square inch at 28 days. Test pieces are required to be stored one day in moist air at 70°F. and the remainder of the time in water at 70°F. It was further provided that the average compressive strength at the age of 28 days shall be at least 35 percent greater than the strength at the age of 7 days. This was done to insure a concrete, the strength of which would definitely increase with age.

The cumulative heat of hydration of the cement, as determined by the special heat of hydration method specified, is limited to not to exceed 65 calories per gram of cement up to the age of 7 days after

mixing the cement with water, and shall not exceed 80 calories per gram of cement up to the age of 28 days after mixing with water. The cement as actually delivered has averaged 53 to 56 calories per gram at 7 days and 60 to 65 calories per gram at 28 days.

In order to determine the relative heat of hardening of various cements and to make tests to determine whether the cement purchased conforms to the specified limits of heat value, special calorimeter equipment and tests developed by the Riverside Cement Company and manufactured by the University of California at Berkeley and not heretofore used in commercial practice, were adopted.

The determination of heat evolved by the hardening process of cement pastes is based upon Hess's law of constant heat summation: "The change in heat content of a system in passing from one state to another is independent of the path whereby the passage is made." Applying this law to the problem of determining the heat of hardening of cement, we must first determine the heat of solution of the dry cement in its initial state. The heats of solution of the cement after reaction with water for 7 and 28 days are then subtracted from the heat of solution of the dry cement; the difference being, respectively, the heat of hardening at 7 and 28 days. In a similar manner the heat of hardening for any period of time may be determined.

In addition to the ordinary complete chemical analysis of the cement, the hypothetical combinations are computed for:

	CHEMICAL COMPOSITION	ABBREVIATED SYMBOL
Tricalcium silicate	$3\,CaO\,SiO_2$	C_3S
Dicalcium silicate	$2\,CaO\,SiO_2$	C_2S
Tricalcium aluminate	$3\,CaO\,Al_2O_3$	C_3A
Tetracalcium aluminoferrite	$4\,CaO\,Al_2O_3\,Fe_2O_3$	C_4AF
Calcium sulphate	$CaSO_4$	

It is possible from these hypothetical combinations or directly from the chemical composition through the work of Hubert Woods of the Riverside Cement Company[1] and R. E. Davis of the University of California to estimate fairly accurately the quantity of heat that will be generated during the hardening process.

The contribution of individual compounds to heat of hardening and also the contribution of each oxide composition to the heat of harden-

ing is shown in table 1 after Woods, Steinour and Starke.[1] Tests on 284,950 barrels of cement for use in Pine Canyon Dam demonstrate clearly that it is possible to predict upon the basis of chemical analysis the heat of hardening of all cements tested within 10 percent and generally much closer to the true values determined by heat of solution methods and after one set of tests have been completed for a given cement its heat of hydration may be computed much more closely from its chemical analysis than by use of the general constants given in table 1.

TABLE 1

Contribution of individual compounds to heat of hardening

(Contribution in calories to heat evolution of one gram of cement for each percent of each compound after Woods, Steinour and Starke.*)

COMPOUNDS	CALORIES AFTER DAYS' HARDENING				
	3	7	28	90	180
3 CaO SiO_2	0.983	1.100	1.142	1.224	1.206
2 CaO SiO_2	0.195	0.181	0.436	0.552	0.526
3 CaO Al_2O_3	1.70	1.88	2.02	1.88	0.218
4 CaO Al_2O_3 Fe_2O_3	0.29	0.43	0.48	0.47	0.73
OR IN TERMS OF OXIDE COMPOSITIONS COMPUTED FROM ABOVE					
CaO	+3.40	+3.92	+3.31	+3.28	+3.29
SiO_2	−5.79	−6.80	−4.93	−4.55	−4.65
Fe_2O_3	−3.2	−3.2	−3.1	−2.9	−2.6
Al_2O_3	−1.1	−1.5	−0.1	−0.4	+0.4

Note. In direct determination of heat from the oxide compositions 0.7 times the amount of SO_3 and any free lime should both be subtracted.

The above values are only approximate, but have generally been found to give results within 10 percent of results from heat of solution tests on the same cement samples.

* See footnote on page 1352.

Test results indicate that fineness of grinding also affects the heat of hardening. Increasing the fineness increases the heat of hardening, but not so rapidly as the strength is increased. In other words for a cement of constant composition the strength fineness ratio will be increased by finer grinding.

The results of laboratory tests on the first 284,950 barrels of cement manufactured for use in Pine Canyon Dam by three of the four mills having the cement contract are summarized in table 2.

TABLE 2

Summary of laboratory cement tests—grand averages

BRAND	QUANTITY	COMPRESSIVE STRENGTH, 1–3 MIX		CONSISTENCY	SETTING TIME		FINENESS (THROUGH 200 MESH)	SOUNDNESS	HEAT OF HYDRATION		CHEMICAL ANALYSIS									HYPOTHETICAL COMBINATION				
		7 days	28 days	MORTAR	Initial	Final			7 days	28 days	SiO_2	Fe_2O_3	Al_2O_3	Total CaO	MgO	SO_3	Insol	Ig Loss	Total	C_3S	C_2S	C_3A	C_4AF	$CaSO_4$
	barrels	*pounds per square inch*	*pounds per square inch*	*per-cent*	*hours*	*hours*	*per-cent*		*calo-ries per gram*	*calo-ries per gram*														
Riverside	112,000	1,538	3,651	10.24	3:01	6:03	93.0	O.K.	52 6	60 5	*23 04	*4 91	*5 23	*58 80	3.76	1 69	0 32	1.22	*98 97	*17 09	*53 17	5.76	*14 94	*2 96
Colton	103,950	1,590	3,531	10.15	3:15	6:22	90 3	O.K.	55 4	64 0	22 57	5 63	5 37	59 44	3.42	1 75	0 27	0 69	98 87	21 34	48 62	4 69	17 13	2 98
Victor	69,000	1,938	4,031	10.15	3:21	5:27	95 4	O.K.	56 1	65 5	26 21	2 04	3 26	64 02	1 61	1 77	0 22	0 86	99 70	31.62	51 25	5 20	6.21	3 01
Monolith																								
Weighted averages																								
Specification requirements		800	2,000		0:60	10:00	85–98		65.0	80.0					5 00	2.00	0.85	4.00				1–6%		

* Note: Values taken from Silo 4 analysis. Complete to May 6, 1933.

Strength of mass concrete in the dam as shown from daily tests taken from the mass concrete in the dam using 0.95 barrels of cement per cubic yard, a cement water ratio of 1.70 (water-cement ratio by weight 0.59) and 6-inch maximum aggregate is shown in figure 1.

At the field laboratory we are able to test up to 600,000 pounds, which is insufficient capacity to test 24- by 48-inch cylinders which should be required for testing of concrete with 6-inch maximum aggregate. However, we have obtained fairly consistent results with 14 by 28-inch cylinders and the full sized aggregate. From the same samples 6- by 12-inch cylinders are cast and aggregate coarser than $1\frac{1}{2}$ inches is screened out.

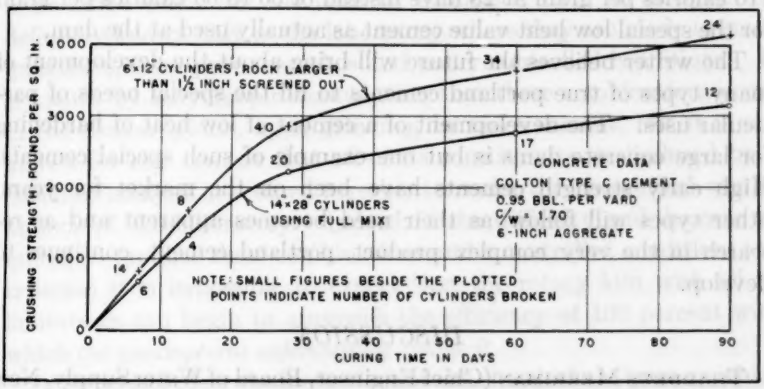

FIG. 1. PASADENA WATER DEPARTMENT, PINE CANYON DAM. STRENGTH OF MASS CONCRETE IN DAM

The specifications require concrete in the mass of the dam to have a minimum strength of 2,000 pounds per square inch at 28 days. Average strengths at this age for 14- by 28-inch cylinders have been 2,200 pounds and for 6- by 12-inch cylinders 2,850 pounds per square inch. Strengths are 3,150 and 4,130 pounds per square inch at 90 days respectively or substantially a 50 percent increase in strength at 90 days over 28 days. This continued increase in strength is due to high dicalcium silicate in the low heat value cement.

A large number of Carlson type strainmeters and thermometers have been installed in the mass concrete of the dam and an excellent record of temperatures is being obtained. These records show the highest temperature so far obtained is 107°F. This temperature was reached in the center of mass where the dam is 210 feet in thickness

and the thermometer 50 feet above foundations. The initial temperature of the concrete mix was 71° and the time required for the rise, three months. In the following three months the temperature fell 1°F. The concrete mix is 0.95 barrels per cubic yard, and one 5 foot lift is poured every three days. It now appears likely that some temperatures higher than 107°F. will occur in the dam where 1.0 barrels per cubic yard of a cement of slightly higher heat of hardening was used.

However, with the rapid pouring rate at Pine Canyon Dam we should have obtained temperature rises approximately 50 percent greater if ordinary commercial cements had been used having 90 to 110 calories per gram at 28 days instead of 60 to 65 calories per gram for the special low heat value cement as actually used at the dam.

The writer believes the future will bring about the development of many types of true portland cements to fill the special needs of particular uses. The development of a cement of low heat of hardening for large concrete dams is but one example of such special cements. High early strength cements have been on the market for years; other types will follow as their need becomes apparent and as research in the very complex product, portland cement continues to develop.

DISCUSSION

THADDEUS MERRIMAN (Chief Engineer, Board of Water Supply, New York, N. Y.): At the close of a "Century of Progress" this paper marks the beginning of a new era in Portland Cement. The barriers that have long stood in the way of developing this material, which is at the very foundation of every engineering structure, have begun to yield and the realization that all "standard" cement is not equally suited for every purpose has taken root in the mind of both engineer and cement producer.

The paper presents the situation with respect to the requirements for a low-heat cement in so clear a manner that any discussion on these points would merely tend to confuse the issues. But in regard to the details of the specifications which involve the tacit assumption that the constituents of a cement always combine together to make certain complete and definite compounds, a word of caution should be said.

It is a curious psychological phenomenon that, as soon as the human mind sees certain things in the form of a specification, it immediately

inclines to adopt them as absolute truth. The recent tendency in this direction as influenced by the Pasadena specifications and by those for the Boulder Dam is to produce the belief that, if one has an analysis of a cement, the compounds it contains may at once be determined by a simple computation.

The case, however, is not as elemental as that. As the author states, these compounds or combinations are purely hypothetical. But he does not emphasize that they are hypothetical in both theory and practice. Let us inquire as to the limitations which beset the determination of these "hypothetical combinations."

In the first place the combinations of lime, silica, alumina, and ferric oxide which are theoretically computed from an analysis are definitely known only in the laboratory where they are made in small quantities, from pure materials and under controlled conditions. It is known by microscopic examination that these combinations occur in the clinker which, upon grinding, becomes cement, but it is not known for any cement that *all* of its constituents as disclosed by a chemical analysis are joined together to make the theoretical combinations of the laboratory. Indeed, if the difficulty and the care required to produce these combinations under controlled conditions is a criterion it is impossible to expect that the rotary kiln with all its limitations can begin to approach the efficiency of 100 percent with which *the assumptions inferentially endow it.*

In the second place the limitations of the chemical analyses on which the computations are based must not be overlooked. A small error in the percentages of the compounds may produce one that is many times as great in the computed percentages of certain of the "combinations."

In the third place the combinations that are formed in the rotary kiln come into being in the presence of substances which are wholly absent in the laboratory. Among others, the raw mix in the kiln contains magnesium, sodium and potassium and there is no knowledge either as to how they enter into the various combinations or as to what effect they have on their formation.

While this brief presentation touches only the more important phases of the matter of specifying and thinking in terms of "constituent combinations," it points out the danger of overemphasis in this direction. It is a human characteristic that things which appear to be new should be welcomed with open arms while other lines of thought which lead to the same end are pushed aside and forgotten.

This matter of percentage combinations is an old story to the writer and, so far as he is aware, it was first developed by Dr. R. J. Colony in connection with studies made by him for the Board of Water Supply of the City of New York in 1918. Since that time its application has been extended by Dr. R. H. Bogue of the Portland Cement Association Fellowship and by others, but its limitations are as sharply defined now as they ever were. For instance, there is no apparent advantage in requiring that a cement shall not contain more than six percent by weight of *tricalcium aluminate* when exactly the same result can be obtained by setting corresponding limits for the alumina and the ferric oxide. The former method, as has been shown, involves many uncertainties and indeterminate factors and tends to inculcate the belief that every cement, no matter how made, contains neither more nor less of the various combinations than the computations indicate. No concept could be more erroneous or lead to a greater sense of false security. Even the chemical analysis itself guarantees nothing, because it tells only a partial story as to how completely the cement has been burned. How then may an arithmetical computation based on non-proven assumptions make the situation clearer? As an extreme case it is possible to put together a mixture of the cement constituents which will analyze just as a cement, but which will have no cementing qualities whatever.

The writer would make it clear that the foregoing is not offered as a criticism, but only as a constructive attempt to visualize the limitations that surround this seemingly new line of thought and to point out to the non-technical user that the science of cement is not yet ready to aver that, "Those things which I think are in Portland cement are surely there." The best and soundest progress is only to be made when we fully understand both the advantages and the shortcomings of our methods. Knowledge and understanding never come through blind adherence to the "substance of things hoped for."

Two other items should be briefly noted. The author refers to the experience "at Arrowrock where serious sloughing of the downstream face has occurred," presumably, as the result of the use of "a cement admixture such as finely ground silica." As to this, the writer was informed by the late A. J. Wiley that the admixture was a finely ground granite which contained much feldspar. The deterioration which has occurred is thus readily understandable.

It is a matter of regret that the Pasadena specifications do not include a tensile test requirement and it is to be hoped that a sufficient

number of such tests will be made on both neat and sand specimens as to completely develop the tensile characteristics of these cements. By cutting our ties with past experience the door is closed to the acquirement of much important knowledge. In this case new and valuable information will be developed with regard to these particular cements, but, in the absence of the tensile characteristics of the cement, its coördination with the results of former years will not be possible.

The characteristics of the cements used at Pine Canyon as disclosed by table 2 of the author's paper indicate that all of them are of much more than average excellence and this is particularly true by reason of their high silica, high ferric oxide, low alumina, and low lime contents. All four of these factors are effective in producing a cement that will withstand sulphate attack and show a maximum of durability under all conditions of exposure.

The author is to be congratulated on the success of his efforts in securing for the city of Pasadena this high quality of cement which, moreover, by reason of its characteristic of low heat liberation is so admirably adapted for the great masonry mass of which it is the most essential part. But it should not be overlooked that the results obtained have, in large measure, been due to the splendid coöperation of the cement producers and the advanced technical methods they have brought to bear in the effort to produce that cement which is best adapted to a particular situation.

GROUND-LEVEL STORAGE AND BOOSTER STATION AT MILWAUKEE, WISCONSIN

By Herbert H. Brown

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The city of Milwaukee has adopted a plan of installing ground-level storage tanks and a booster station. The purpose of this installation is to alleviate low pressure conditions during periods of peak consumption in the outlying sections of the city by concentrating a large storage capacity and a large pumping capacity in the center of the district where needed.

The water works distribution system of the city of Milwaukee is divided into a low service district and a high service district. Essentially the low service district comprises the down town section of the city and adjoining land, all at a relatively low elevation. Water is pumped at 60 pounds pressure into a large reservoir which serves the entire low service area. This phase of the distribution system does not present any difficulty and, therefore, does not enter into the problem under discussion.

The high service district completely surrounds the low service area, comprises territory at much higher elevations, and is supplied by direct pumpage from two major pumping stations. It is in the extreme outlying sections of this district, 8 to 15 miles from the pumping stations, that low pressure conditions were found to exist during periods of high pumpage. The installation of additional pumping units at the stations would not help these low pressure areas due to the resulting high friction losses in the distribution system.

PROPOSED PLANS

A comprehensive survey and study was made and four definite plans were analyzed as a means of improving the conditions in the distribution system. Briefly, the first plan considered involved the construction of a major pumping station on the south side and the installation of necessary tunnels and discharge mains to properly

serve it. The cost of this work was estimated at over five million dollars. This plan was rejected because of the large expenditures required for initial installation as well as yearly operation and because of the relatively short periods of time each year that the station would be in operation.

The second plan studied proposed the installation of elevated steel tanks on high land. Due to the urgency of the situation, one 1½ million gallon tank was erected in the southwesterly section of the city in 1930 and another 1½ million gallon tank was installed in the westerly section in 1931. These tanks have functioned satisfactorily, but the scope of their influence is naturally limited. In planning for the future under a scheme of elevated storage, a study indicated that 16 such tanks would be necessary to adequately serve the city until the 1950 period. The possibility of securing proper sites for the installation of such a large number of tanks was considered quite remote. In addition, the continued and concerted objections of property owners to having elevated tanks erected near their homes made the problem of further installations increasingly difficult. While this plan would cost considerably less than the cost of a major pumping station, it was still higher than either of the following plans.

The third plan which was considered proposed the installation of ground storage tanks in conjunction with small booster stations. Under this scheme water would be taken from the low service district to fill the tanks and then repumped into the high service district during periods of peak consumption. The main objection to this plan was that the pumping capacity of each installation was limited to serve only a rather small area unless a large expenditure was made to lay new feeder mains. The entire plan was quite expensive and did not have the feature of centralized control as secured by the next plan.

PLAN ADOPTED

The fourth plan proposed was the natural evolution of the previous plans and combines all features at a considerably reduced expenditure. This plan was the one adopted and consists essentially of installing a large reservoir capacity and pumping capacity at one point in the outlying section of the high service district near the center of consumption. Ultimately two 6,000,000 gallon ground-level storage tanks will be built with a booster station containing

four 30 m.g.d. motor driven centrifugal pumping units. It is estimated that the entire project will cost approximately $450,000.

A site was selected at a point about 6 miles from the pumping stations along a street in which one 30-, one 36- and one 12-inch water main were installed. These mains will provide ample outlet capacity for the booster station and will conduct the water in all directions. The tanks will be filled during the night by the pressure in the street mains. Water will be pumped out of the tanks the following afternoon during the sprinkling peak and discharged into the distribution system at the same pressure maintained at the pumping stations. Thus, by re-establishing the static pressure at a point about 6 miles from the pumping station, the pressure beyond this point will be boosted by the amount of frictional loss which would be normally realized between the pumping stations and the site chosen for the booster station. This loss amounts to approximately 30 pounds during periods of peak consumption.

One 6,000,000 gallon tank was constructed in the fall of 1932 and the booster station is now under construction. One pumping unit will be installed this year and the other three units will be installed in the future as required. It is contemplated that the station and tank will be used only during the summer months covering the period of high peak consumption. The tank, mains and equipment will be drained over the winter period and the station will be closed.

BOOSTER STATION

Because of this low "use-factor," the building was designed to be small, stripped of ornamentation and to be as simple and practical as possible. The station will be 40 feet by 60 feet (inside dimensions) in size, built of concrete below grade and brickwork above grade. A gas-fired hot air furnace will be used to automatically keep the temperature in the building above the freezing point. The suction piping will extend in the shape of a U between tanks, passing through the building in a 6 foot floor trench. The pumping units will rest on the basement floor level, spanning the suction piping and trench.

The pumping units will consist of motor-driven single stage 24″ x 20″ centrifugal pumps of 30 m.g.d. capacity against 250 foot head. The capacity will vary about 10 percent due to the fluctuating positive head from the tanks. The synchronous motors driving the

pumps will be 1,500 H. P. each, operating at 900 R.P.M. with 2,300 volt, 60 cycle 3 phase current. Two incoming lines at 26,400 volts will be brought into an interior sub-station containing one 500,000 KVA oil circuit breaker and four 1,250 KVA transformers.

Standard hydraulically operated gate valves will be installed in the suction line to each pump. No priming equipment will be necessary because of the positive head on the pumps from the tanks. A plug type of check valve will be installed in the discharge line from each pump and operated by a hydraulic cylinder. The control for each check valve will consist of a solenoid operated 4-way valve and a pressure operated Mercoid switch. The 4-way valve will be piped to the hydraulic cylinder in the customary manner and the Mercoid connected to the upstream side of the check valve. The electrical circuit between the solenoid of the 4-way valve and the Mercoid will be connected with the D. C. field on the main motor. The check valve, therefore, will not open unless the motor is operating and not until the water discharged from the pump is at a predetermined pressure.

An interesting hydraulic problem presented itself in providing an arrangement to fill the storage tanks. Two 10-inch by-pass lines have been designed to extend from a point on the street side of the check valve in two of the discharge lines to the 48-inch suction pipe in the floor trench. Due to the comparatively low elevation of the main in the street a minimum of 90 pounds must be maintained on it while filling the tanks in order to prevent the high points of the distribution system from being without water. The maximum pressure on the tank side of these filling arrangements will be 16 pounds. This high differential will cause a velocity of about 50 feet per second through each 10-inch main which has been designed to fill one tank in a period of 4 to 5 hours. A plug type of valve operated by a hydraulic cylinder will be used for controlling the rate of filling. The essential portion of the control apparatus consists of a solenoid operated 4-way valve which will be connected in the normal manner to the hydraulic cylinder of the plug valve. The solenoid will be connected to a float switch placed on the overflow line of the storage tank. When the tank is full of water, a float will trip this switch, breaking the circuit to the control valve and de-energizing the solenoids on the 4-way valve, thus closing the plug valve. In series with this electrical circuit will be placed a double throw Mercoid switch connected to receive the pressure in the main discharge line

and so adjusted to make or break the circuit between predetermined limits of pressure. This part of the control will permit the plug valve to open the proper amount in order to fill the tank without allowing the street pressure to drop excessively.

DESCRIPTION OF TANK

The 6,000,000 gallon storage tank constructed in 1932 is of the ground storage type. It was completely welded in the field by the electric arc fusion process and to the writer's knowledge is the largest all welded steel tank in the water works field in this country. The only riveted members used on the job were the structural steel trusses, columns, rafters and purlins utilized for supporting the roof. The tank is 165 feet in diameter and is 37 feet 6 inches high to the overflow line. It is supported on a 12 inch concrete slab which was poured directly on the ground and pitched toward the center. The tank bottom was formed out of $\frac{3}{8}$-inch steel plates resting on a $\frac{1}{2}$-inch layer of asphalt placed directly on the 12-inch slab. The bottom plates were butt welded with 3-inch by $\frac{1}{4}$-inch chill strips placed under all joints.

The cylindrical section of the tank is made up of six courses of plates varying in thickness from $1\frac{3}{16}$ inches at the bottom to $\frac{3}{8}$-inch at the top. Each course is composed of 13 plates, each plate about 40 feet long and formed to the diameter of the tank, with the vertical seams staggered in relation to the adjoining courses. A 5-inch by 3-inch by $\frac{3}{8}$-inch shelf angle was welded to the inside of the top plate to stiffen the upper course and to act as a support for the roof trusses. The bottom edge of each course was machined and the machined edges of adjoining courses joined with fillet welds both inside and outside. The vertical seams are solid butt welds. Three 18-inch by 24-inch manholes, with the covers supported on davits, were placed in the lower course of the shell.

The roof is supported on 16 steel trusses placed radially and all trusses fastened to one column at the center. The outer ends of all trusses are supported on the tank side. Each truss is also supported at its mid-point by an intermediate column. The base plates on all columns are welded directly to the bottom or floor plate of the tank. Rafters are framed between trusses, and purlins are so framed into the rafters at slightly different elevations to form a conical roof. Copper bearing roof plates ($\frac{3}{16}$-inch) rest directly on the purlins and are designed to carry a 25 pound snow load. The roof has a vertical rise of $2\frac{1}{2}$ inches for each foot of horizontal length.

A 16 foot diameter pent-house 2 feet high was placed at the apex of the roof for two reasons. First, this type of construction permits a heavy wire mesh screen to be placed near the top of the tank for ventilating the interior. Second, this type of construction was adopted for architectural reasons because it was felt that it would break the monotony of a large plain roof coming to an apex.

As a further method or aid toward ventilation, a $\frac{3}{4}$-inch no. 9 gauge wire screen was placed around the periphery of the tank at the top of the side walls. This screen is 9 inches in height and was tack welded to the tank plates, roof and purlins.

An overflow trough 12-inch by 12-inch in cross-section was formed around the entire inside of the tank. Six collecting boxes, each 10 inches wide by 12 inches high and 30 inches long, have been fastened to the bottom of the overflow trough at equidistant points. Six overflow steel pipes, 8 inches in diameter, lead from these boxes through the tank wall and down to the ground where they will be connected to the storm sewer. Slip joints have been provided in the vertical run of these overflow pipes to take care of any expansion.

One 48-inch pipe will be laid between the tank and the booster station and will serve as both a supply and a drain line. This pipe line will be installed in a concrete box tunnel under the tank foundation to a point approximately 30 feet from its center. The end of the pipe line will be connected to a cylindrical discharge basin 10 feet in diameter and 7 feet 9 inches high, the top of which is welded to the tank bottom. This basin has been designed to permit the water in the tank bottom to be withdrawn to the lowest level possible before a swirling action takes place and breaks the pump suction.

An inside and outside painters trolley have been installed on the tank. The outside trolley rides on a Z-bar welded to the tank side and the inside trolley rides on the edge of the vertical plate forming the overflow trough. In addition to the regular inside and outside tank ladders, another ladder was installed on the center column. This ladder extends to the pent-house above, and by means of a narrow runway and a removable section of wire screen, access is provided from the roof of the tank.

The entire tank, with the exception of the structural steel, received three coats of paint after erection and sand blasting in the field. The first coat of paint to be applied on all steel work consisted of chromate of lead. The inside of the tank then received two additional coats of chromate of lead. The outside of the tank was finished with two coats of aluminum paint. The structural

steel was not sand blasted, but received its first coat of chromate of lead in the shop followed by two field coats of chromate of lead. The lower side of the bottom plates of the tank have been sand blasted, primed with one coat of chromate of lead and covered with one heavy coat of asphalt paint.

The tank weighs approximately 660 tons and was furnished and erected by The A. O. Smith Corporation of Milwaukee. The contract was awarded on a cost basis for a sum not to exceed $89,500.00 and with the provision that all men working in the field were to be residents of the city of Milwaukee.

A separate contract in the amount of $8,735.00 was awarded for the construction of the concrete foundations and tunnel.

ERECTION EQUIPMENT

Two 4 ton tractor cranes with 40 foot booms handled most of the material entering into the construction of this tank. They unloaded the steel, handled the floor plates for painting and then set same, erected all side plates except the top course, and were used for general utility purposes. An 8 ton tractor crane with a 75 foot boom was used to erect the top course of the tank side, raise the roof plates, and erect the outer roof trusses, purlins and rafters. The center and intermediate columns and the center trusses were erected by means of a derrick and steam hoist. The derrick had an 85 foot boom supported by a mast with two stiff legs, eliminating the necessity of guy lines. Two side sheets were left out until the structural steel was erected; the derrick was then dismantled and removed and the tank closed.

The current for welding was supplied by 10 motor generator sets; each set was used by one welder. Each set was driven by a six cylinder gasoline engine and had 100 feet of cable attached as a ground and 300 foot of cable as a power line to the hand arc. The current used was at 45 volts and varied from 150 to 500 amperes depending upon the thickness of the parent metal, the size of the weld rod and the speed at which the weld was being made.

The air for operating the peening and chipping hammers was supplied by a 600 cubic foot, single stage, water cooled compressor. The air pressure was maintained at 110 pounds at the compressor. A pipe line was installed on the ground around the tank with valved taps to which air hose could be conveniently connected.

Cage scaffolds about 2½ feet by 4 feet in plan were hung from the

top edge of the side sheets by means of roller supports and were used by the welders and peeners. Each welder could roll his cage around the tank as his work progressed. When a course was completed, a crane would lift the cage to the next course.

A large pipe framework for supporting a scaffold was built especially for this job and was used on the inside for erection purposes. The framework was 40 feet long, 10 feet wide and supported on six rubber tired wheels set at an angle to facilitate easy movement along the tank side. Three 12-inch steel pipes 38 feet long and spaced 20 feet apart were raised as posts or columns along one side of this framework. A one-half ton chain block was fastened to the top of each post and was used to raise or lower the scaffold. The scaffold was so built that it slid on and was guided by each post.

Six large "C" clamps, each 12 feet high and weighing approximately one ton, had a 4-inch slot 9 feet long and were used to bring each plate of the side wall in alignment with the course below.

WELDING PROCEDURE

All welding was performed by the electric arc fusion method using covered weld rods. This method necessitated considerable peening and chipping to remove all slag from the heart of the weld. Peening also helped to expand the metal and thereby relieve the shrinkage stress set up when the metal cooled. Weld rods varied in diameter from $\frac{3}{16}$- to $\frac{7}{16}$-inch depending upon the thickness of the weld and parent metal, type of weld, and speed of welding. All butt joints were built by several applications or layers of weld metal with considerable peening performed between applications. Five applications were required to build up the joints on the heavier plates and two or three applications were used on the $\frac{3}{8}$-inch plates.

Floor plates

While the foundation was being prepared, the $\frac{3}{8}$-inch floor plates were delivered to the site, spread out on the ground, and sandblasted and painted on one side. After the chill strips had been set to line and grade on the concrete foundation and the asphalt filler had been spread and rolled, the floor plates were set in position and tack welded. As the welding of the joints progressed, considerable warping and buckling of the plates occurred. This warping was evidently due to the excessive heat of the welds setting up stresses in the plates and due to the temperature changes during the day. The plates were

exposed to the sun on some very hot days last September when the temperatures at night dropped close to the freezing point. However, it was decided to delay the floor welding until after the side and roof plates were in position. Later some of the welds in the badly warped plates were cut out, the plates were hammered down flat and the joints re-welded. But cold weather arrived before the roof was placed. This caused the tank side sheets to contract and buckle the floor plates. Where the plates were not welded it caused them to overlap and it was necessary to cut off about an inch from one side of the plate before the weld could be made. Several of the warped plates were left in the floor to take care of the expansion in the side sheets when the tank is filled and when the temperature rises.

From the experience gained by the construction described above there are some changes which would be recommended for future work. The most important recommendation is that the floor plates should be lap welded instead of butt welded. Lap welding will reduce or eliminate the warping and will be a great deal less expensive. Chill strips can be eliminated under the joints. It is further recommended that the tank side be completely erected before the floor is welded and that the floor plates be welded in warm weather. Also that the floor plate under the side sheet be placed about 6 inches higher than normal with the foundation pitching sharply from a point 12 inches from the side sheet. If the steel plates were laid in warm weather to conform to this contour of the concrete, they could contract in cold weather without causing any buckling.

Side or shell plates

All plates used in the shell of the tank were 40 feet long, 6 feet 3 inches to 6 feet 9 inches wide and were rolled and machined at the plant of the manufacturer. The ends of the plates which were welded to form the vertical joints of the tank were machined by taking a single tapered cut so as to form a V-joint before welding. The bottom of each plate was machined by taking a cut off each edge, thus leaving a small horizontal section for bearing on the lower plate.

Each plate was set in position and tack welded to adjoining plates with miscellaneous pieces of scrap bar material to temporarily hold the plate in position. Six large C-clamps were used to bring each plate in line with the course below. A 12 pound plumb bob suspended by a wire was used to check the vertical alignment. The closing plate in each course was fabricated slightly longer, and after

the circumference and correct length was measured, the extra length was cut off with a gas torch.

The vertical joints were welded from the inside. A filler rod was placed on the outside of the joint to prevent the metal from blowing through the joint. Later the rods were burned or melted out and the space filled with weld metal, thus leaving a full depth weld. All horizontal joints were made with double fillet welds. It is of particular interest that the first course of the shell was fastened directly to the floor plates with this same type of weld without using a stiffening angle or other structural member. It was found that unless the weld on the outside of the tank was made first, it was difficult to keep the side sheet vertical. Experience also indicated that these welds should be made slower and that more peening should be done than on the usual weld.

Roof plates

It was first proposed to butt weld all roof plates but when it was tried considerable warping resulted. This was due to the difficulty of holding such a thin plate in relation to its size. These plates were approximately 5 feet by 19 feet by $\frac{3}{16}$-inch thick. Also, it was found that peening was quite difficult because the weld metal was hard and brittle. This was thought to have been caused by the presence of copper in the plates.

After this experience it was decided to lap weld all roof plates. They were welded on the ground in groups of three to make panels which ranged in size from 8 feet by 19 feet to 12 feet by 19 feet. They were then hoisted to the top of the structure by means of a special T-frame built of I-beams and moved into position by means of a cable lead through a snatch block on the peak of the roof. The panels were tack welded along the edge to the roof trusses, purlins and rafters. After several panels were set in place, the welders would follow and make a complete lap weld. Very little warping occurred in the roof welding after the lap weld was adopted.

TWENTY YEARS' PROGRESS IN CENTRIFUGAL WATER WORKS PUMPS

By A. Peterson

(De Laval Steam Turbine Company, Trenton, N. J.)

It has been only during the last 25 or 30 years that the centrifugal pump has found a wide application in water works pumping plants, although during the last 20 years practically to the exclusion of any other kind of pump. For certain applications however this type of pump has been known and used for a considerably longer time. The first centrifugal pump resembling the present-day pump was, it is generally believed, first designed and constructed in the United States a little over a century ago. This pump, the so-called Massachusetts pump as built in 1818, may be considered to be the forerunner of the modern centrifugal pump, the design of the casing being very similar to that of the modern pump, although the impeller was only a radial vane paddle wheel. In 1846 Andrews brought out a centrifugal pump with an impeller of the closed type with backwardly curved vanes, so we can properly at this time celebrate the 100th anniversary of the modern centrifugal pump.

The early centrifugal pumps were suitable only for low head and low speed, and for this reason found very little use in water works where heads above 150 feet are the rule. It was only at the end of the last and the beginning of the present century that, spurred by the commercial development of the steam turbine and of the high speed electric motor, the centrifugal pump began to make rapid progress. Incidentally, it is a year more than a half century ago, or in 1882, that the first practical steam turbine was invented by Dr. Gustaf De Laval in Sweden, to be followed in the following year by the Parsons turbine in England. Dr. De Laval was not only a pioneer in the turbine field, but he also saw the advantages of high steam pressures and temperatures, and in 1897 had in operation turbines using steam at pressures as high as 2800 pounds per square inch and at temperatures of 700° to 750°F., while in 1899 he built a single stage centrifugal pump which, running at 15,400 r.p.m., developed 590 feet

head and delivered 185 g.p.m. These early developments were prophetic of the modern application of high steam pressures and also of the recent use of single stage boiler feed pumps on naval vessels and of high pressures per stage in multistage pumps.

As with anything new, many years were taken in selling the centrifugal pump idea to water works engineers. As an uninterrupted supply of water is imperative, water works engineers are generally conservative, and being used to large low speed pumping engines, could only with difficulty be convinced that the small high speed centrifugal pump would be just as reliable and would have just as long a life.

The De Laval Company began building centrifugal pumps and steam turbines in the United States in the year 1901. The following figures show the total capacity of centrifugal pumps supplied to municipal water works at successive periods by the De Laval Steam Turbine Company:

Year	Total capacity, m.g.d.
1907	25
1910	150
1915	1,350
1920	3,500
1930	14,000

It will be seen that the application of centrifugal pumps in the water works field has increased tremendously during the last 20 years, and with this increase in use there has naturally been progress, not only due to experience of and competition between manufacturers, but also to extensive research work and to a better understanding of hydraulic laws, which progress I will attempt to outline in this paper. Closely linked with the centrifugal pump is its driver, and some reference will be made to the progress and development of the latter particularly the steam turbine, as affecting the overall efficiency of the plant.

NATURE OF PROGRESS

Progress in centrifugal pumps may be classified under the following headings:

1. Mechanical construction
2. Materials
3. Operating characteristics
4. Efficiency and means for sustaining efficiency

1. The mechanical construction of the centrifugal water works pump has been changed very little during the past 20 years, and outside of changes in proportions a pump built in 1913 is practically the same as one built today. While some manufacturers have made improvements and changes in construction, they are of only minor nature. There has recently been a tendency to adopt ball bearings for large water works pumps, but this can hardly be termed progress.

2. Practically the same statement holds in regard to materials of construction. In view of the almost complete absence of difficulties with the water works pumps that can be traced to materials, there has been no reason for making changes. Instead of using ordinary cast iron for pump cases, many manufacturers have now standardized on so-called semi-steel, which is obtainable in tensile strengths up to 45,000 pounds per square inch. Government bronze is still widely used for impellers and other bronze parts, except where greater strength than is obtainable with such bronze is required.

3. Under operating characteristics may be considered improvements in the operation of centrifugal pumps in respect to noise and cavitation. Almost the only complaints that a manufacturer receives concerning the operation of a water works pump relate to noise and cavitation, which often result in corrosion of the impeller. Based upon experience and recent research work, such difficulties can, almost without exception, be traced to a speed too high for the conditions. The maximum speed at which a centrifugal pump may operate with assurance of freedom from cavitation and noise is determined by capacity, head and suction conditions. Progress toward overcoming this evil has quite recently been made through the general acceptance among centrifugal pump builders of the principle that centrifugal pumps should not be operated above certain maximum speeds. This should benefit the water works engineer because he will not now, as was often the case before, be compelled to select from among a number of bids the pump that is priced lowest merely due to operating at too high a speed. The limitation of speed is more valuable to the water works man than to many other users of centrifugal pumps because if efficiencies are equal he is generally restricted to the cheapest pump that complies with the specifications.

To show how closely builders agree as to maximum speeds, I have plotted in figure 1 from the Hydraulic Society's curves the maximum revolutions per minute for a capacity of 1 m.g.d. for different heads and suction conditions. To obtain the maximum speed for some

other capacity, divide the revolutions per minute given by the curves by the square root of the capacity specified. For instance, while it should be possible to operate a 1 m.g.d. pump at 200 feet head and 15 feet suction lift at a speed of 4430 r.p.m. a 15 m.g.d. pump for the same head and suction lift should not be run at a speed above $\frac{4430}{\sqrt{15}}=1142$ r.p.m.

The curves are for single stage, double suction pumps. A single suction pump should operate at a lower maximum speed than does a double suction pump, and the approximate maximum speed for a

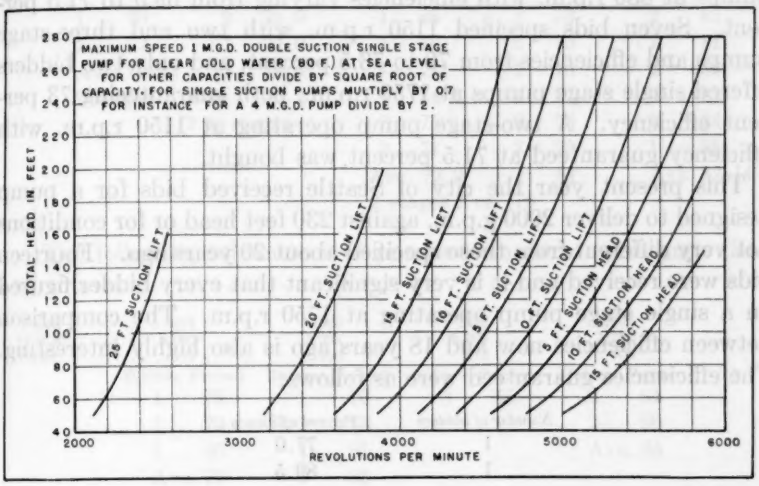

FIG. 1

single suction pump may be obtained by multiplying the double suction pump speed by 0.7.

4. The greatest strides made in the centrifugal pump during the past two decades have been in respect to efficiency. Twenty years ago an efficiency of 80 per cent was considered very good, even for a comparatively large water works pump, while today a water works engineer would not, and could not, afford to take such a pump as a gift, but would expect an efficiency close to 90 per cent. Efficiencies even above 90 per cent have been shown by accurate field tests on water works pumps using approximately 1800 b.h.p.

The improvement in efficiencies has not resulted in increased cost of pumps, but rather the contrary.

Fifteen to twenty years ago pumps having two or three stages were used for total heads between 200 and 250 feet; today, for the same heads single stage pumps give better efficiency and naturally cost less than did the old two-stage pumps.

A tabulation of pump bids which I have recently come upon illustrates this point very clearly. Eighteen years ago, or in 1915, the city of Seattle received bids for a pump designed to deliver 2000 g.p.m. against 190 feet total head. In three bids the speed offered was 690 r.p.m., the number of stages varying from two to five, and the efficiencies from 70 to 72 percent. Three bidders offered two-stage pumps at 880 r.p.m. with efficiencies varying from 69.5 to 71.5 percent. Seven bids specified 1150 r.p.m. with two and three-stage pumps and efficiencies from 70 to 73.5 percent, and only two bidders offered single stage pumps at 1750 r.p.m., both guaranteeing 73 percent efficiency. A two-stage pump operating at 1150 r.p.m. with efficiency guaranteed at 71.5 percent was bought.

This present year the city of Seattle received bids for a pump designed to deliver 2000 g.p.m. against 230 feet head or for conditions not very different from those specified about 20 years ago. Fourteen bids were received and it is very significant that every bidder figured on a single stage pump operating at 1750 r.p.m. The comparison between efficiencies now and 18 years ago is also highly interesting. The efficiencies guaranteed were as follows:

Number of bidders	*Percent efficiency*
1	77.0
1	80.5
4	82.0
1	82.5
2	83.0
1	83.5
1	83.7
1	84.0
1	84.5
1	86.0

Thus, today, Seattle can buy a single stage pump giving from 15 to 20 percent higher efficiency than did the two-stage pump bought 18 years ago. This means a saving in power consumption of from 15 to 18 kw. or a possible saving in cost of current of more than $1,000.00 per year. Considering the cost of a new pump and even of a new motor, the city would probably make a very good investment by throwing out the old pump and buying a new one.

I have looked up a great number of tabulations of bids on municipal water works jobs dating back 15 to 20 years, and in most cases present-day pumps would show just as great improvement in efficiency as in the example just referred to.

The improvement in efficiencies of small pumps has been comparatively greater than that of large pumps. To illustrate this I have picked out a few typical cases from available tabulations. They follow:

Year.... 1919		1923		1928		1933		1933	
G.P.M....1,050		1,050		850		700		1,400	
Feet 300		475		266		150		150	
Bidders	*Percent*	*Bidders*	*Percent*	*Bidders*	*Percent*	*Bidders*	*Percent*	*Bidders*	*Percent*
1	69	1	66.5	1	66	1	72	1	79
1	70	2	70.0	1	68	3	73	2	80
1	72	1	71.0	1	70	3	75	2	81
Ave.	70.33	1	73.5	1	71	1	76	2	82
2 stages		Ave.	70.2	4	74	1	77	4	83
		2–4 stages		2	75	2	78	2	84
				2	77	2	79	1	85
				Ave.	72.9	1	81	Ave.	82.14
				2 stages	Ave. 76				

The following tabulations of pumps of moderate size may also be of interest:

Year 1916		1920		1928		1932	
G.P.M. 5,000		5,000		5,200		5,250	
Feet 171		310		170		200	
Bidders	*Percent*	*Bidders*	*Percent*	*Bidders*	*Percent*	*Bidders*	*Percent*
1	78	1	76	3	85	2	84
1	79	2	78			2	86
1	80	1	81			Ave.	85
Ave.	79	1	83				
		Ave.	79.2				

In regard to comparatively large water works pumps, that is 15 m.g.d. capacity and above for heads above 150 feet, very few installations had been made as far back as 20 years ago. Further, up to quite recently most of such installations were of the turbine driven type and tabulation of bids, therefore, do not as a rule give any data on pump efficiencies.

However, on a motor driven water works pump of 30 m.g.d. capacity against 250 feet head installed in 1917 or 16 years ago, a pump efficiency of 85.97 percent was obtained on the official acceptance test. Today efficiencies of about 90 percent are obtained on pumps of this size. On the recent acceptance test of a motor driven pump designed for 55 m.g.d. against 160 feet head a pump efficiency of 90.7 percent was obtained, the overall efficiency being 88.005 percent.

Of some interest is a tabulation of bids received only about two months ago for six 50 m.g.d. pumps against 136 feet head at a speed of 514 r.p.m. The pump efficiency guarantees were as follows:

Bidders	*Percent*
1	91.5
2	90.0
1	89.5
1	89.0
1	88.0

Since the life of a water works pump is ordinarily much greater than 20 years, many old pumps now in operation should without question be replaced on account of possible improvement in efficiency. These old pumps in many cases require repairs or replacements of

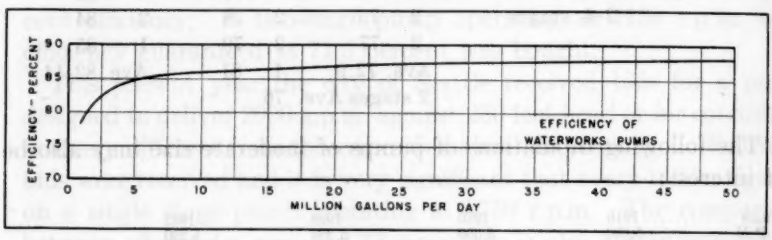

FIG. 2

parts, the purchase price of which could better be applied to the cost of a new and efficient pump. This has actually happened in several instances with which I am familiar. In the present times of unemployment and distress it is earnestly to be recommended that water works engineers canvass all old pumping equipment and obtain estimates on cost of replacements, which will not only help to relieve unemployment, but also effect an annual cash saving for the city. Figure 2 shows approximately present-day efficiencies of single stage water works pumps for heads between 125 and 225 feet and may serve as a guide to water works engineers in estimating what savings can be made by replacing old pumps by new.

During the past 20 years improvements in efficiency have been made not only in centrifugal pumps, but also in the driver, such as the electric motor and steam turbine. The efficiencies of electric motors have not been improved as much as have those of centrifugal pumps. However, extremely high motor efficiencies are now being

obtained, even from comparatively small motors. For instance, efficiencies of 95.5 percent up to 97 percent have been obtained from synchronous motors in sizes from 400 horsepower to 1800 horsepower.

The efficiencies guaranteed on the synchronous motors for the six pumps referred to before are quite interesting. The motors were of 1500 horsepower size and the lowest guarantee submitted by the seven bidders was 97.4 percent and the highest 98.41 percent.

The efficiencies of steam turbines, on the other hand, have improved materially during the past 20 years. In addition to this steam pressures and temperatures have been increased so that duties not dreamed of 20 years ago are now being obtained. The present year

TABLE 1

Data for water works pumps in Chicago

	YEAR OF INSTALLATION			
	1922	1924	1926	1928
Steam press, lb./sq. in.	175	175	175	300
Superheat, degrees	150	150	150	200
Capacity, m.g.d., specified	60	60	60	75
Capacity, m.g.d., developed on test	60	59	61.28	74.9
Head, specified, feet	150	150	150	150
Head, developed on test, feet	151.51	151.51	149.76	153.17
Duty actually obtained on official test	154.362	172.0	181.8	218.2
Overall Rankine cycle efficiency, turbine and pump, percent	51.8	56.9	56.8	63.0

may be considered as the 20th anniversary of the modern turbine driven water works pump, as it was in 1913 that the first large unit of this type, consisting of a multistage geared turbine driving a single stage pump, was installed in the Ross Pumping Station, city of Pittsburgh. On the official acceptance test, it developed a duty which established a record of 119,540,590 foot-pounds per 1000 pounds of steam when delivering 101,935,000 gallons per day against a head of 58.765 feet and using steam at a pressure of 151 pounds per square inch gage.

About 14 years later, or in 1927, another similar unit was installed in the same station, the pump being designed for the same capacity and head but the steam conditions being changed to 315 pounds per square inch gage and 200°F superheat. This unit developed 183,900-

000 foot-pounds per 1000 pound of steam, a gain of about 54 percent over the original unit. This higher duty is, of course, largely due to the better steam conditions, but there is nevertheless an increase in Rankine cycle efficiency of the turbine of approximately 14 percent. The turbine of this unit was designed for bleeding 14,000 pounds of steam per hour at 40 pounds per square inch pressure which, although it results in higher overall plant efficiency, lowers the Rankine cycle efficiency when running straight condensing, the condition on which the duty given above is based.

Table 1, exhibiting duties obtained from turbine driven water works pumps at city of Chicago over a period of 6 years, shows that due to improvement in turbine efficiencies and higher steam pressures and superheats, there has been an increase in duty of 41.5 percent.

In view of the fact that all these units were equipped with identical pump casings and impellers, the improvement in overall Rankine cycle efficiency represents the gain in turbine efficiency, which for the 1928 turbine is about 21 percent higher than for the 1922 unit.

CHANGES IN DRIVE

Up to about five years ago the majority of centrifugal water works pumps of more than 500 horsepower size were driven by steam turbines, but the last few years have seen a growing tendency to install electrically operated pumps, even of power requirements of 2000 horsepower and above, and a few Diesel engine driven water works pumps have also been installed. Where rates for electric power are extremely low, electrification may be economical but each case should be decided on its merits.

In comparing steam turbine drive with electric operation, the greater flexibility of the former is often lost sight of. In water works service, particularly with direct pumping, there often is appreciable variation not only in capacity, but also in pressures required. On account of the necessity of having spare units, it is not always practicable to split up the maximum pumping requirement into several units designed for widely varying conditions, and it is in such cases that the turbine driven unit on account of the possibility of varying the speed without seriously affecting its efficiency, makes by far the best combination. Partial load and capacity efficiencies have in recent years been improved, both of steam turbines and of centrifugal pumps, so that good economy is being obtained over a wide range of capacity and head.

During the last year or two the tendency to come back to steam turbine drive for even comparatively small units is quite significant. Notable examples are installations at Memphis, Tenn., involving

TABLE 2

Steam turbine driven water works pumps

WHERE INSTALLED	CAPACITY, M.G.D.	TOTAL HEAD, FEET	HORSE POWER RATING OF TURBINE	STEAM PRESS, LB. PER SQ. IN. GAGE	SUPERHEAT, °F.	DUTY, MILLION FOOT POUNDS PER 1,000 POUNDS STEAM	REMARKS
Commonwealth Water Co., Summit, N. J.	6	340	870	250	100	166.2	300 k.w. alternator attached
Atlanta	40	255	2,060	175	100	184.7	
Knoxville	15	350	1,100	290	200	201.9	300 k.w. DC Generator attached 2 units
Louisville	40	200	1,650	250	200	190.3	
Milwaukee	40	280	2,350	200	100	176.0	
Pittsburgh	50	57	685	315	200	175.0	
Pittsburgh	100	57	1,160	315	200	183.9	
St. Louis	60	360	4,460	300	200	168.26	Duty on BTU basis, 2 units
Chicago	75	150	2,300	300	200	218.2	4 units
Chicago	60	235	2,850	175	125	198.5	2 units
Memphis	15	175	550	200	120		2 units, tests not completed
Newton	4.25	272	550	230	125		200 k.w. alternator. Tests not completed
Newton	6	295	775	230	125		200 kw. alternator. Tests not completed
Newton	8	340	1,000	230	125		200 kw. alternator. Tests not completed

units of about 550 horsepower, and three units at Newton, Mass., of from 550 to 1000 horsepower size. In many instances, as at Birmingham, Ala., Knoxville, Nashville, Newton, etc., the economy of the turbine driven unit has been greatly improved by attaching to it a

generator for operating low lift pumps and other equipment around the pumping station. This should always be considered in connection with any new installation because even if the main pumping load is small the electrical load may be such that a turbine driven unit will be a good investment. For instance, on one of the Newton units, the normal pumping load is only 230 b.h.p. but a 200 k.w.

TABLE 3

Electric motor driven water works pumps

WHERE INSTALLED	CAPACITY, M.G.D.	TOTAL HEAD, FEET	HORSE POWER OF MOTOR	OVERALL EFFICIENCY PUMP AND MOTOR
Council Bluffs	8	260	500	83.5
Saginaw	4.6	175	200	78.6
Saginaw	8	175	350	81.0
Saginaw	12	175	500	83.4
Baltimore	15	193.5	600	84.7
Baltimore	32.3	150	1,000	86.1
Baltimore	44	155	1,400	84.4
Baltimore	55	160	1,800	88.0
Oklahoma City	12	195	500	82.6
St. Petersburg, Fla.	15.8	150	500	83.5
Minneapolis	40	65	450	83.09
Flint, Mich.	12	175	450	82.9
Flint, Mich.	15	175	600	85.7
Mahoning Valley Sanitary District	5	275	350	78.48
Mahoning Valley Sanitary District	10	275	650	81.28
Mahoning Valley Sanitary District	20	275	1,400	83.93
Grosse Point Farms	4.9	175	200	83.5
Grosse Point Farms	7.35	175	300	82.5
Trenton, N. J.	20	155	700	84.9
Minneapolis	30	240	1,600	84.51
Suffolk Water Co.	4	170	150	81.9
Suffolk Water Co.	6	150	200	82.9

alternator, also driven by the turbine, makes the rating a little over 500 horsepower, which improves the efficiency of the turbine quite materially.

A list of recent notable installations of water works pumps, together with operating data, is shown in tables 2 and 3. This list discloses the trend towards higher steam pressures and temperatures, with resulting excellent duties and also discloses the excellent efficiencies obtained from modern electric driven pumps.

MAINTENANCE OF HIGH EFFICIENCY

Notable progress has been made in the maintenance of high efficiencies as now obtained with centrifugal pumps. A high initial efficiency is not of much value unless the water works operator can be assured that this efficiency will be maintained for a reasonable length of time, and much progress has been made in this respect. Practically the only point where wear affects the efficiency of a centrifugal pump is at the joint between discharge and suction chambers. The casing and impeller are, or should be, protected at this point from wear by removable rings. With the present tendency to use single stage pumps for heads above 200 feet, the leakage through wearing rings, particularly in small and moderate size pumps, becomes a considerable item, and naturally manufacturers make the clearances at this joint as small as possible in order to be able to guarantee high efficiencies.

However, due to the action of the high velocity water passing between the rings, of shaft deflection and of possible whipping of the shaft, wear of the rings occurs with consequent reduction in efficiency. An ideal pump should not depend upon small ring clearances for its efficiency and it is here that the labyrinth wearing ring stands out as one of the most significant developments in centrifugal pump design. Although this type of ring was developed and used more than 20 years ago, it has been only within recent years that users of centrifugal pumps have fully appreciated its advantages. The superiority of the labyrinth wearing ring over the flat ring is clearly demonstrated in an excellent paper on "Leakage Loss and Axial Thrust in Centrifugal Pumps," presented by A. J. Stepanoff of the Byron-Jackson Company, at the 1931 Annual Meeting of the American Society of Mechanical Engineers. I recommend that all users of centrifugal pumps obtain a copy of this valuable paper. For the benefit of those who may not send for it I will elaborate somewhat on the reasons for the advantages of the labyrinth wearing ring, mostly taken from my discussion of Mr. Stepanoff's paper:

Mr. Stepanoff's tests indicate that for the same clearance the single labyrinth ring, gives from 41 to 46.6 percent less leakage than the plain ring. The results of our tests were that the double labyrinth ring, gives about one-third of the leakage of the plain ring.

This is of considerable importance in centrifugal pump design, because not only does it result in higher initial efficiencies, but also in better sustained efficiencies. In view of the one-third lower velocity of the water through the

labyrinth ring, there naturally will be less wear of this type of ring than of the flat ring, and this stands out particularly in the case of pumps handling gritty water.

Practically the only reason why the efficiency of a centrifugal pump drops off by use is wear in the rings and, therefore, anything that can be done to reduce the amount of wear is of considerable advantage.

Leakage losses are something that cannot be seen, and unless the pump is tested at regular intervals it may be operated for a considerable time with worn rings and at very much reduced efficiency.

As a rule, labyrinth rings are not used so much for the purpose of obtaining a higher initial efficiency as for the purpose of permitting larger clearances without a sacrifice in efficiency. This is also important as it is not then necessary to resort to machine the revolving ring after it is put on the impeller. This is objectionable because it is not always convenient for a customer in case he orders a replacement ring to take the pump rotor to a machine shop to have a finishing cut taken on the impeller ring.

TABLE 4

Operating results at Philadelphia Pumping Station

	UNIT NO. 4		UNIT NO. 5	
	5-hour test, 1-20-33	Acceptance test, 1-22-27	5-hour test, 1-31-33	Acceptance test, 3-3-27
Capacity, m.g.d.	26.833	26.364	26.418	26.402
Total head, feet	401.06	401.29	404.62	404.0
Water horsepower	1,887.96	1,835	1,875.31	1,872
Electric horsepower	2,249.18	2,240	2,233.06	2,248
Overall efficiency, per cent	83.9	82.7	83.9	83.3

Another advantage that stands out in connection with large clearance labyrinth rings is that for a certain fixed amount of wear the leakage increases a smaller percentage than for the same amount of wear in the small clearance plain rings.

Assuming that a plain ring with 0.012 inch clearance on the diameter has a leakage of 5 percent and that the same amount of leakage is obtained with a labyrinth ring with 0.030 inch clearance on the diameter, and that both rings have worn 0.012 inch on the diameter, we have a loss in efficiency in the case of the flat ring of 5 percent and with the labyrinth ring a loss of only 2 percent, assuming no change in coefficient of discharge. This example clearly demonstrates the great advantage of the labyrinth ring.

Operating records showing maintained high efficiency, as at Minneapolis and Baltimore, would not be possible without labyrinth rings having large initial clearances.

Similar excellent results have been obtained on two 25 m.g.d. pumps

installed in the Shawmont Pumping Station, Philadelphia, as shown in table 4. After 6 years service without any repairs or renewals of parts these pumps gave practically the same efficiency as on the official acceptance test. It should be noted that the head per stage is fairly high, or a little over 200 feet, which makes the performance record still more remarkable.

THE FUTURE

Although it is more or less futile to predict what the future has in store for us in the way of progress or improvements, it is nevertheless fairly safe to state that great improvement in maximum efficiency of centrifugal pumps cannot be expected. Efficiencies of around 90 percent are now being obtained on pumps of moderate size, and when considering the amount and nature of losses in a centrifugal pump, such as leakage, bearing, packing and impeller friction, and the loss in conversion of the large kinetic energy of the water leaving the impeller into pressure, it is easy to realize that not much improvement can be looked for.

I have heard statements that we will soon see efficiencies of about 94 percent on centrifugal pumps. Judging by guarantees on very small pumps, this conclusion might be reached, but I personally doubt that such efficiencies are possible from commercial pumps. Based upon the 1933 Progress Report on Hydraulic Power Development, hydraulic turbine efficiencies have reached almost 94 percent, and it is stated that the opportunity for further improvement is small. This applies to units involving considerably more power than is usual in the water works field. Furthermore, a hydraulic turbine is inherently more efficient than a centrifugal pump. The efficiency of a hydraulic turbine depends mainly upon the conversion of pressure head into velocity; at least this applies to water turbines for moderate and high heads, while in a centrifugal pump high velocities must be converted into pressure. The former conversion can be accomplished much more efficiently than the latter.

I am therefore inclined to agree with a statement which appeared in the November, 1932, issue of *Power* (Hydraulic Turbine and Pump Combined in a Single Unit, by F. A. Allner) that the best pump has from 50 to 75 percent greater losses than has the best hydraulic turbine. With maximum efficiencies of about 90 percent from centrifugal pumps and 94 percent from hydraulic turbines, these two important hydraulic machines may therefore be considered as being at

the same status of development, and much further improvement in this respect cannot be expected.

SUMMARY

The most important developments in centrifugal water works pumps during the last 20 years may be briefly summarized as follows:

(1) Efficiencies of small pumps have been improved from 15 to 20 percent and of large pumps from 8 to 10 percent.

(2) Twenty years ago single stage pumps were seldom used for heads higher than 100 to 125 feet, while today they are used for heads as high as 250 feet and high efficiencies are obtained at such heads.

(3) Due to a greater knowledge of factors affecting noise and cavitation, which has resulted in placing limitation on inlet tip speed of impeller vanes, and thus revolutions, the useful range of centrifugal pumps, particularly in regard to suction lifts, has been extended.

(4) By proper selection of pump size and speed more satisfactory operation at high suction lifts can now be obtained than was the case 20 years ago.

(5) The efficiency of the driver of centrifugal water works pumps has also been improved during the last 20 years and this applies particularly to steam turbines and more so to the comparatively small turbines as generally used for driving water works pumps. I am probably not far wrong in stating that the Rankine cycle efficiency of the average present-day water works turbine is about 20 percent higher than it was 20 years ago and this coupled with the modern high steam pressures and temperatures results in duties that make steam turbine drive for water works pumps a very attractive and economical proposition.

Twenty years ago there was some hesitancy on the part of water works engineers to accept as fully reliable and satisfactory the high speed helical gear reduction as invariably used on turbine driven water works pumps. However, such gears have now been in continuous satisfactory service for 20 years and in the meantime improvements have been made in gear-cutting methods and design so that present-day gears are far superior to those turned out 20 years ago.

BITUMINOUS PIPE COATINGS

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Sometime ago the necessity for investigation of bituminous pipe coatings was indicated by the occurrence of some distressing events in Detroit. On one occasion when a new pipe was placed in service, a large portion of the coating became detached and found its way into many industrial plants and private homes. On several other occasions, the placing in service of new mains produced obnoxious tastes and odors. These occurrences, combined with the desire to procure a satisfactory coating for wash water troughs in the filtration plants, led us to make an exhaustive series of tests and observations on bituminous pipe coating with the thought of preparing tentative specifications and means of testing for conformance with the specifications. In doing this work it was felt essential to devote some time to the literature on corrosion and its prevention. Before proceeding to the subject proper, a very brief résumé of these subjects follows.

CORROSION

Corrosion is a term applied to the deterioration of metals. It transforms iron and steel in commercial forms to iron oxide or rust. Corrosion operates unceasingly and presents one of the greatest problems with which man must contend. The magnitude of this problem may be realized by the estimate of one authority of an annual world-loss of one and one-half billions of dollars or the destruction of half as much steel as is produced annually in the United States.

Much study has been devoted to the causes of corrosion and many hypotheses have been evolved. While none have been accepted universally, two stand out most prominently, the acidic and the electrochemical. The acid hypothesis assumes that the production of hydrogen ions is caused by presence of acid, thereby causing initial corrosion whereas the electro-chemical theory does not require that condition.

The proponents of both hypothesis agree that corrosion requires the presence of moisture and oxygen. The majority at present accept the electro-chemical hypothesis, also believing that the dominating factor in corrosion in natural waters is the dissolved oxygen content.

Natural waters vary from a very weak acid as indicated by a pH value of 5.0 to a weak base as indicated by a pH value of 10.0. In this pH range oxygen concentration and velocity of flow are the two most important corrosion factors. Temperature and composition of water also influence the rate of corrosion, but not to such a degree as dissolved oxygen. Rate of corrosion in natural waters has been found to be directly proportional to their oxygen content, while the effect of hydrogen-ion concentration has been found to be negligible.

The presence of large amounts of carbon dioxide (CO_2) in natural waters influences the process of corrosion. Carbon dioxide when dissolved in water forms carbonic acid (H_2CO_3) which partly dissociates and increases the number of hydrogen ions that react with the iron surface. Not only does carbon dioxide influence corrosion, but it will weaken or dissolve any protecting coating of iron rust or mineral scale that has formed upon the surface of the metal. A scale-dissolving water would keep the iron surface clean and in easy access to the dissolved oxygen and, therefore, open to maximum rate of corrosion regardless of the presence of scale forming salts. The coagulum precipitation method of clarifying water always charges the water with carbon dioxide.

One of the most serious problems which confronts water works men today is the tuberculation which forms on the inside of both steel and cast iron pipe lines. The effect of tuberculation upon pipe lines, laid prior to the use of protective coatings, has been severe. A tubercle has been described as a limpet like structure arising from the surface of iron, and consisting, essentially, of black magnetic oxide of iron (FeO) in the central portion and of red hydrous iron oxide (Fe_2O_3) in the outside layers. Careful study of these tubercles by Reddick and Linderman[1] has brought out the fact that tuberculation in iron pipes can be caused by certain microscopical organisms of bacterial nature, which precipitate iron from solutions of iron salts.

As the preceding paragraphs indicate, the corrosion of the interior

[1] "Tuberculation of Mains as Affected by Bacteria," Water Works and Sewerage, October, 1931.

surface of iron and steel water mains is an electro-chemical process accomplished through the agency of water, and the rate at which corrosion proceeds is governed by the composition of the metal, nature and composition of the water, dissolved oxygen and carbon dioxide concentration and velocity of flow.

The corrosion of exterior surfaces of iron and steel water mains presents a slightly different picture. Although the process of corrosion might be of an electro-chemical nature, it is augmented by the character of the soil and soil-water in which the pipes are laid. Under bad soil conditions water pipes, particularly those of steel, are subject to severe corrosion. Certain soils and soil waters are known to contain alkalies, organic acids, and in some cases inorganic acids. The soil water might also be heavily charged with corrosive gases, such as carbon dioxide and hydrogen sulfide. Poorly drained soils are generally far more corrosive than well drained soils.

Electrolysis, due to stray electric currents leaking from electric conduits, will also deteriorate metal pipe, causing severe pitting upon surface of pipes. An instance occurred in Detroit last year where electrolysis had caused numerous pit holes, some of which were $\frac{1}{8}$-inch deep, to appear upon the surface of a 48-inch steel water main. The stray electric current was found to have originated from an electric conduit located within 6 feet of the water main.

Internal corrosion of water pipes produces incrustation, tuberculation and red water (water containing iron rust), incrustation and tuberculation will, in time, decrease the carrying capacity of the pipes, and at the same time the latter condition will cause severe pitting. Red water has an objectionable appearance and taste, and stains sinks, bathroom fixtures and clothes.

To remedy these undesirable conditions it is necessary either to have the pipe replaced or reconditioned (and both are expensive remedies).

External corrosion of water pipes would, in time, result in a break at some point in the line. This would mean disrupted service to the consumer and considerable cost to the Water Department through having to replace or repair the broken section.

It was formerly considered that cast iron pipe, used in water distributing systems, would last a life-time, not being subject to corrosion to any great degree from water, alkalies or acids, but it has been proven and accepted by prominent engineers that many thou-

sands of miles of cast iron pipe are seriously damaged through electrolytic action resulting from contact with stray electric currents.

While corrosion is much slower in cast iron mains than in steel, it is certain, nevertheless, to take place in the form of tuberculation on the interior surfaces, resulting in severe damage to the pipe and decreased carrying capacity. Tuberculation has been found on the inside of a large number of old cast iron water mains that have been uncovered during the past few years.

In new cast iron pipe, of course, it may be a matter of years before tuberculation progresses to such a degree as to seriously impair the capacity of the pipe and to make cleaning necessary. When the pipe has been cleaned, however, tuberculation builds up much faster than before. This, it is believed, is because removal of the tubercles exposes a bare iron surface.

Thus, it is evident, that with possible stray electric currents causing severe pitting of the exterior surfaces of cast iron pipe and tuberculation causing pitting and reduced capacity on the interior of the pipe, it is just as essential that cast iron water mains be as adequately protected against these forms of corrosion as steel mains.

The loss from corrosion of iron and steel pipes by water works systems throughout the United States cannot be definitely stated, but an approximate idea can be obtained from the fact that about $20,000,000 is expended annually in the water, oil and gas industries for replacement losses.

The distributing systems of water works represents a large proportion of their invested capital. The proper protection of the tremendous mileage of underground water mains is of vital and growing importance.

The average expenditure for protection of iron and steel pipes against corrosion is 1.6 cents per foot of pipe for each inch in diameter. This is a very small amount when compared with the cost of reconditioning or replacement while endeavoring to maintain efficient and dependable water service.

When the effects of external and internal corrosion of water pipes are taken into consideration it becomes apparent that corrosion is a serious problem in the water works field, and that steps should be taken to protect, internally and externally, every foot of iron or steel water pipe against the ravages of corrosion, thereby increasing the life of the pipe and, consequently, decreasing the cost of repairs and replacements.

PREVENTION OF CORROSION

Although the problem of corrosion prevention is far from solution, enormous progress in methods of prevention has been made. The results of this study of conditions causing corrosion and the use of proper materials to inhibit these conditions, have considerably lengthened the life of iron and steel water mains.

The most practical and positive protection is to prevent any of the corrosive agents from reaching the surface of the metal. This can only be accomplished by coating the pipe with a substance which will adhere firmly to the metal surface, and which will be impermeable to water and every other form of possible electrolyte. Such a coating must retain these properties for a long period of time and in addition withstand all normal atmospheric conditions and such mechanical actions and service conditions as may occur.

In order economically to accomplish successful corrosion protection over a period of years, protective coatings must possess certain definite properties. The most important of these are:

Penetration—into the pits and pores of the surface to be protected.

Stability—physical and chemical. The coating must retain its protective qualities after long exposure to corrosive conditions.

Chemical neutrality—neither acid nor alkali, in order to prevent reaction with the metal.

Hiding power—to produce an adequate protective film with the least number of coats, saving time, labor and material.

Adhesiveness—to provide a strong, permanent bond with the coated surface.

Elasticity—the ability to withstand temperature changes, vibration, reasonable bending and movement of the coated metal.

Resistance and imperviousness—to acids, alkalis, electric currents, water, gasses and other corrosive influences.

In addition to the foregoing requirements, the coating to be acceptable, must be easily applied, be reasonable in cost and must not contaminate the water supply by increasing the hardness, or imparting objectionable tastes and odors. Needless to say, the coating must contain no poisonous substances soluble in water.

Ordinary red lead, graphite and other pigment paints using linseed oil as a solvent are totally unsuited for the protection of iron and steel when underground or underwater. These paints have a comparatively low initial adhesive strength, which lessens steadily after application. They lack penetrating power. The fact that they dry by

oxidation causes the film to become porous in a short time. The linseed oil used as a base, being a glyceride of fatty acids, may become saponified by the water, and also offers slight resistance to aggressive gases or mild acids. Lead and oil paints, at the best, break down in 2 to 5 years. This is caused by the fact that not more than three coats of lead and oil paint can be applied without destroying the flexible qualities of the coating. Three coats of such paint equal about $\frac{8}{100}$ inch in thickness which is insufficient to afford lasting protection.

Another type of coating which has recently appeared on the market is a clear, transparent, blended composition of neutral vegetable and mineral oils. This type has great penetration and while it may be an excellent rust preventive for iron and steel which is not submerged in water, tests of this material made under water were not successful. Test panels, examined after being submerged for 30 days in water, showed that the transparent film had become soft, white, opaque, corrugated, rust spots developed and the coating was easily removed. When the coating was removed, it was seen that the metal was badly rusted.

It is not the purpose of this paper to discuss the use of cement linings, although, this type of lining has been used with varying degrees of success. The use of cement may offer some difficulties inasmuch as it may become loose on the surface or crack or it may render the water caustic for a period of time or it may become porous. Much thought is being given to the removal of the objectionable features of cement lining and it may be that in the near future it will be regarded as an ideal coating for water mains.

Bituminous protective coatings have been used in the United States for many years, and due to their successful protective powers have found a wide-spread use. Practically all steel pipes are coated inside and out with bituminous compounds before being laid under ground. Cast iron pipe, as a rule, is coated only on the interior surfaces. Past experience has indicated a water pipe properly coated with a bituminous coating of sufficient thickness, compounded so that it will possess required adhesive strength, texture, chemical inertness, dielectric properties, longevity and possessing other necessary properties will assure a pipe life of many years.

BITUMINOUS COATINGS

Virtually all experts in engineering fields substantiate the fact that bituminous coatings consisting of properly selected basic materials,

correctly proportioned and combined with the correct amount of inhibitive mineral substances produce a coating which will give satisfactory protection. The selection of proper ingredients is essential, due to the varying physical characteristics of the basic bitumens which constitute the greatest proportion of the finished product. Basic bitumens containing free acids, paraffin and sulfur should be avoided as these substances are at times unstable, acting as stimulants to corrosion. Of course, proper manufacture of the finished product is of equal importance, with the proper selection of basic ingredients, in producing a satisfactory coating.

It might be well at this time to define our conception of an ideal pipe coating. The coating should adhere tenaciously to the surface of the pipe, be inert to acid and alkaline soil and soil water, stand handling and transporting, possess proper elasticity and toughness, be impervious to electrical currents, be of sufficient thickness to be durable, be resistant to solar, climatic, and atmospheric conditions and must contain no free acid or sulfur. The ideal pipe coating must retain these conditions for an extended period of years. Ordinary asphalt and coal tar-base coatings while slightly more effective than red lead, and graphite paints, have in many cases deteriorated very rapidly after five years service. Some deviation may be allowed from the above qualifications after a survey of soil and climatic conditions in the section in which the pipe is to be laid has been made. For instance, resistance to acid is not so important when an alkaline soil is encountered nor resistance to extremely low temperature in warm sections.

Before discussing the relative merits of asphalt base and coal-tar base coatings, it would be well to state that both types are widely used. Many authorities consider the asphalt base as superior, although the coal-tar base coatings are becoming popular due to their greater resistance to the action of soil and soil water. Practically all new steel mains are coated with asphalt base materials, as they are more elastic and not so susceptible to temperature changes; coal-tar base coatings are used extensively for cast iron mains. One prominent manufacturer does not recommend the use of asphaltic base coatings for cast iron pipe giving as his reason that coal-tar base coatings adhere better and have given satisfactory results for 50 years. Both types of coatings give satisfactory protection when properly prepared and used, but as Abraham[2] states, asphalts and coal-tar pitch do not readily amalgamate except in restrictive proportions and are rarely used together.

[2] "Asphalts and Allied Substances," Third edition.

The preservative qualities of native asphalts have been known for thousands of years. The ancient Egyptian mummies were embalmed in natural asphalt and perfectly preserved bones of prehistoric animals have been discovered in the LaBrea natural asphalt beds in California.

Although the use of native asphalts produces a coating superior to that obtained from the use of petroleum asphalts, most manufacturers of coating use the petroleum asphalts as a base due to their lower cost. Petroleum asphalts are still residues obtained from the steam distillation of crude petroleum and vary considerably in their suitability as a base, owing to their lack of stability as well as the presence of paraffin and sulfur. Their quality is improved by blowing air through them at high temperature, producing the product known as blown asphalt. It is the opinion of the writers that a protective coating containing native asphalt as its base although more expensive is justified due to its longer life.

In general, asphaltic coatings are superior to coal-tar coatings. The asphaltic coatings are pliable, do not become brittle or check at low temperature, sag or flow at extreme summer heat, possess the necessary flexibility and toughness to stand wear and tear encountered in transit and during installation and have sufficient ductility to resist movement of installed pipe. Inasmuch as these qualities are lacking in coal-tar coatings, it is much more difficult to procure a satisfactory installed coated pipe, with coal-tar coating than with asphalt coating, but if an undamaged coal-tar coating is obtained after installation it will be more resistant to the disintegrative action of water and other corrosive influences than asphalt coating. An additional disadvantage in the use of coal-tar coatings is the possibility of objectionable tastes and odors being imparted to the water by the reaction between free chlorine and certain coal-tar compounds.

It is suggested that when the pipe is to be coated at its place of manufacture, an asphalt base coating be specified, insuring proper protection during transit and storage and decreasing the need of recoating in the field. If the pipe is to be coated at the site of installation, a coal-tar coating should be specified because of its greater resistance to corrosion, providing that it will not impart objectionable taste, is not applied in cold weather and when coated is laid immediately.

This need for caution in applying coal-tar coatings is indicated by the guarantee of the makers of a well-known coal-tar product which is widely and satisfactorily used. This manufacturer guarantees his

product to outlast any other coating, which can be used, under any and all soil and water conditions, but states emphatically that it must be applied at the site of the pipe laying, and must not be exposed to severe climatic conditions. In Detroit a short section of 84-inch main was coated inside and out with a $\frac{1}{4}$-inch coating of this material during the winter months of 1931. Examination of this pipe recently revealed the presence of large blisters on the surface of this material, some of which had broken, exposing the bare metal. Inasmuch as the coating itself showed no sign of disintegration it is assumed that a faulty bond was obtained by applying the coating in cold weather.

Bituminous protective coatings for use on iron and steel water mains are commercially available in several forms, namely, the hot dip, paints, varnishes and emulsion. The hot dip coating is the solid form and is usually applied at the pipe mill by immersing a section of pipe which has been preheated to about 400°F., in a tank containing the molten coating. The pipe is allowed to remain in the tank for 15 to 20 minutes (the temperature being maintained at about 400°F.), after which it is allowed to drain and cool in a warm room. Asphalt coatings, containing little mineral matter are best suited for use in dipping tanks as excess mineral matter settles, causing an undesirable coking action. Coal-tar-base coatings do not adhere well to the metal when dipped, because of their quick cooling properties. Hot dip coatings are applied in the field after heating the coating until it liquifies and applying by brushing or the centrifugal method. In order to obtain a good bond it is necessary to apply a priming coat (bituminous paint containing a large percentage of solvent) when hot dip is applied in the field.

Bituminous paints are of two classes—an asphalt base with a petroleum distillate solvent or a coal-tar base with a coal-tar distillate solvent. These paints, known generally as solvent paints, usually contain about 60 percent base. They are intended to dry by spontaneous evaporation of the solvent. These paints can be applied by brushing or spraying. These paints are also known as "cold application coatings" as heating of the pipe is not required nor is a prime coat necessary.

Bituminous varnishes are merely bituminous paints containing substantial proportions of certain animal or vegetable drying oils or possibly fatty-acid pitches. They differ from paints in hardening by oxidation of drying constituents rather than by evaporation of the

solvent. The purpose of these saponifiable ingredients is to toughen the coating.

Bituminous emulsions are dispersions of bituminous substances, usually asphaltic, in water attained through the use of an emulsifying agent, either organic or inorganic. Inasmuch as this type of coating is not widely used, it would seem to the writers that it perhaps is not as efficient as the other types.

Various substanees are incorporated in the bituminous bases of certain brands of hot-dip coating and bituminous paints. The most important of these ingredients are mineral fillers, animal or vegetable drying oils or fats, resins and waxes. The functions of these are to harden and toughen the coating or to cheapen it. Mineral fillers when powdered to pass a 200 mesh-sieve and used in quantities of not over 10 to 15 percent apparently improve the coating, otherwise their effects are harmful. Animal and vegetable drying oils or fats are used only in bituminous paints. Their purpose is to prolong the protective life of the coating and while they may be of value when used above water, use of these materials under water has not been successful as when exposed to water for a period of time the material becomes porous, losing its protective powers.

The unsuitability of bituminous paints containing animal or vegetable drying oils for use under water was demonstrated at Detroit in the following manner. A number of wash water troughs were coated with three brands of bituminous paints, whose bases contained approximately 20 percent of saponifiable matter in the form of drying oils, fats or possible fatty acid pitches and at the same time other troughs were coated with bituminous paints, the bases of which contained no saponifiable matter. An inspection of these troughs after two years time revealed the following:—troughs coated with the material containing saponifiable matter showed large numbers of rust spots and tubercles on both exterior and interior surfaces and the coating was soft, friable and blistered whereas the troughs coated with paint minus saponifiable matter showed but few rust spots or tubercles, and the coating appeared to be in good condition.

Resins, waxes and asbestos fibre have also been used in bituminous coatings. Resins and waxes should not be used to any degree, as these substances probably cause the coating to become brittle in time, resulting in cracking and checking. Bituminous paint containing a considerable amount of asbestos fibre has been used experimentally

on wash water troughs at Detroit. This material has not been in service long enough to warrant any statement as to its suitability.

The writers believe that hot-dip coatings for water pipe afford more protection than cold dip coatings, due to the greater thickness of coating which may be obtained. Hot dips give coatings ranging from $\frac{1}{32}$- to $\frac{1}{8}$-inch in thickness, the average being $\frac{1}{16}$-inch. Coatings greater than $\frac{1}{8}$-inch in thickness do not adhere well. Cold applications (bituminous paints) usually produce a coating of less than $\frac{1}{64}$-inch, this thickness, of course, being governed by the percentage of base in the paint and the number of coats applied. Due to the fact that the life of water mains is governed largely by the quality and thickness of their coating, it would seem to be more economical to apply hot-dip coatings rather than cold applications, even though the first cost of the hot-dip might be the higher.

TESTING OF BITUMINOUS COATINGS

During the several years in which we have been making laboratory and field tests on bituminous protective coatings, it has come to our notice that very few water works laboratories in the United States have made any attempt to evaluate this type of coating through the medium of specific tests. It seems that most of the coating is accepted as the result of "Sales Talk" and consequently an unsatisfactory coating is often obtained.

We have tested a number of bituminous hot and cold application coatings and have rejected the majority of them because of their unsuitability as protective coatings. In all probability some of these rejected materials would have been used had they not been tested and serious difficulties might have developed.

There are two methods of testing coatings—field testing and laboratory testing. These two used in conjunction, furnish the best information, but when field testing is not possible a laboratory test will differentiate between a good and bad coating. A laboratory analysis should always be made, as it gives the composition and physical characteristics of the material, which are necessary for the preparation of detailed specification.

Field testing gives the better picture of the manner in which coating will protect pipe. In making a field test, a piece of metal, similar in composition to the pipe to be used, is coated with the sample and buried in the soil in which the main is to be laid. After a period of at least one year it is examined for any deterioration of coating and

appearance of rust spots on the coating or metal. The extent of time necessary for a field test is a draw-back.

Up to the present time in Detroit we have not made any soil field tests, but as mentioned before we have made field tests on bituminous cold application coatings submerged in water, which gave us much valuable information. It is our intention to perform soil field tests sometime in the near future.

There are certain forms of special equipment that are used in performing such physical tests as "Hardness," "Penetration," "Ductility," and "Adhesiveness" which, undoubtedly, aid in obtaining the most accurate results, but in Detroit we have found that it has not been absolutely necessary to purchase this expensive apparatus in order to determine the suitability of a coating. Of course, while this apparatus is not strictly essential it is quite desirable, consequently, to those laboratories that can afford the expenditure we recommend the purchase of this equipment. In preparing our series of laboratory tests and specifications we have found the 3rd Edition of "Asphalts and Allied Substances" by Abraham to be very valuable both as a text and reference book.

In formulating our methods of analysis for hot and cold application coatings we have used some tests given by Abraham, some used by manufacturers, and some devised in our own laboratory. In preparing these methods the scheme has been to use simple tests which will give a good index of the qualities of the coating with the thought that the physical tests are more important than chemical tests in determining the resistance of a coating to water, acids, and alkali and in determining its adhesiveness, toughness, pliability, hardness, susceptibility to temperature changes and its aptitude to impart objectionable tastes and odors to water. The only chemical tests made are those which determine the character of the base in hot-dip coatings and which determine the percentage and character of base and solvent in bituminous paints.

In the analysis of a hot-dip coating, the tests have been grouped under four headings—physical characteristics, physical tests, thermal tests and chemical tests. The tests performed under each heading are as follows:

PHYSICAL CHARACTERISTICS

Luster at room temperature. This indicates the manner in which light is reflected from a freshly fractured surface and may be bright, greasy, waxy or dull.

Consistency at room temperature. This test is rather rough and is judged by forcing a pencil point into the material and noting the degree of penetration. It is recorded very soft, soft, moderately soft, moderately hard, hard or very hard.

Pliability at room temperature. A piece of the material is bent, using the thumb and initial finger of both hands. It is recorded as being pliable if material does not break and brittle if it does.

Specific gravity at 77°F. Performed as outlined under "Analytical Balance Method" in third edition of Abraham's "Asphalt and Allied Substances" page 656.

Physical tests

Pliability at room temperature. A sheet tin panel (4 by 6 inches) coated with the material is bent over a steel rod ($\frac{1}{4}$-inch diameter) until the ends of the sheet meet. The coating is then examined for the appearance of cracks along the bent area and whether it flakes or pulls away from panel.

Sag test. A steel panel (4 by 6 by 0.08 inches) coated with the material and on which a line has been inscribed lengthwise in the center of the plate, is subjected to a temperature of 140°F. for three hours, the panel being maintained in a vertical position. At the end of this period it is noted as to whether or not the inscribed line has sagged.

Cold test. After subjecting a coated steel panel to a temperature of 32°F. for 24 hours, the panel is tapped lightly with a small metallic instrument, immediately after removing from the cold atmosphere. The degree of chipping from the plate is then noted.

Acid test. A coated machine bolt ($\frac{5}{8}$ by 4 inches) is immersed in a (5 percent by volume) solution of sulphuric acid for 48 hours. After immersion the test piece is examined for deterioration or pitting of the coating and corrosion of the metal surface immediately beneath the coating.

Alkali test. This procedure is similar to the acid test except that a 20 percent solution of sodium hydroxide is substituted for the acid solution.

Water test. A coated steel panel is immersed in flowing tap water for seven days. It is then examined for deterioration or pitting of coating, or any change from its original characteristics. The test piece should also be inspected for the presence of rust spots on the surface of the metal beneath coating.

Taste test. A coated sheet-tin panel is immersed in 1.5 liters of

chlorinated water at room temperature for eight hours. Intensity and kind of taste and odor of the water at the end of this time is noted.

Method of preparations of test pieces used in above tests. Panels and bolts are first pickled for one-half hour in 10 percent (by volume) sulphuric acid, removed and washed first with water, then with dilute ammonium hydroxide and again with water, being sure that all particles of loose scale are removed. After drying, the pieces are heated thoroughly on a hot plate.

The coating is prepared by first breaking it into small pieces and then melting slowly in a metal container over a Bunsen burner until the mass is a homogeneous fluid. Rapid heating causes coking which will impair the quality of the coating.

The heated panels and bolts are coated by dipping in the melted coating and swirling around several times. They are removed and after draining allowed to dry at room temperature. The cooled coating should have a thickness from $\frac{1}{32}$- to $\frac{1}{16}$-inch. If coating is less than $\frac{1}{32}$-inch, the test-piece should be recoated. The tin and steel panels, which are all of the same size can be easily handled with crucible tongs, but a piece of copper wire attached to the threaded end is more satisfactory for dipping bolts.

As it is not possible to use figures to represent the results of these tests, the terms—good, poor, etc. are used. Some judgment must be used in selecting the proper term to indicate results, but after a little experience, no difficulty should be encountered.

It is also suggested that notes be kept on these tests recording the luster, thickness, conditions of surface, and any peculiarities which have developed after test. These notes will prove valuable for future reference and comparison.

Thermal tests

Volatile matter. A 50 gram sample is heated in an oven at 165°C. (329°F.) for 5 hours. The loss of weight, after cooling, represents the volatile matter.

Softening point—ring and ball method. See page 687, Abraham's "Asphalts and Allied Substances."

Flash and fire points (open cup). See page 706, Abraham's "Asphalts and Allied Substances."

Chemical tests

Solubility in carbon bisulfide.

Non-mineral matter insoluble in carbon bisulfide (free carbon).

Mineral matter (ash).

These three determinations are given on pages 718 and 719, Abraham's "Asphalts and Allied Substances."

Destructive distillation. A 100 to 200 gram sample is placed in a weighed 500 cc. distillation flask, in which a 300°C. thermometer graduated to 1°C. is inserted so that the thermometer bulb is opposite the delivery tube. The distillation flask is connected to an upright condenser (the Soxhlet Condenser is satisfactory) by means of an adapter. The flask is then heated with the full flame of a Bunsen burner. The distillate is caught in a 150 cc. Soxhlet extraction flask. The distillation is continued for 30 minutes after the first drop has passed into the receiving flask. Initial and maximum temperatures are recorded. The percentage of distillate is determined from the loss in weight of cooled distillation flask, containing the residue. The amount of water passing over with the distillate is estimated (by volume) by settling in a graduated cylinder.

The nature of the distillate enables one to determine the character of the base. Distillates from asphaltic bases are liquid, brown or reddish brown in color, have a specific gravity of 0.74 to 0.87 at 25°C., and a strong hydrogen sulfide odor. Distillates from coal-tar bases are either orange or red solids or else liquids from which crystals tend to separate. Their specific gravity ranges from 0.98 to 1.07 at 25°C. and they possess a strong naphthalene odor. The character of distillates from mixture of asphalt and coal-tar bases varies.

TESTING OF BITUMINOUS PAINTS

The use of bituminous materials for cold application as protective coatings has increased considerably, which has resulted in the need for methods of tests and analysis. A method for the testing of bituminous paints and varnishes (cold application) has been developed at Detroit and is as follows:

Analysis

Consistency at room temperature. Stir the sample thoroughly with a glass rod ($\frac{5}{16}$-inch diameter) remove rod and gauge viscosity by noting rate at which paint flows from rod. Record as very liquid, liquid, viscous and very viscous. As this test is purely arbitrary it is of no value in comparing the results from different laboratories.

Estimation of solvent. See page 823, Abraham's "Asphalts and

Allied Substances," Steam Distillation. Results are reported as percent by weight.

Estimation of base. This is the difference between percent of solvent and 100 percent.

Estimation of water. See page 556, A.S.T.M. Standard Methods of 1930, Part 2 (Non-metallic Materials). Results are reported as percent by volume.

Loss on heating. A 50 to 75 gram sample is heated in a weighed porcelain dish for 5 hours at 165°C. The loss in weight indicates the amount of solvent plus any volatile matter present in the base.

The surface of the base from the "Loss on Heating" test is always examined, to discover if a hard, brittle, and glossy film has been formed over the surface of the base. The formation of this film would tend to indicate the probable presence of some kind of fatty matter, which could be either animal or vegetable drying oils or fats or fatty-acid pitches. The absence of this film would indicate that no fatty ingredients exist in the base.

Drying test at room temperature. The upper surface of a 4 by 6 inch steel place, placed in a horizontal position, is coated to a thickness of approximately $\frac{1}{64}$- to $\frac{1}{32}$-inch. The time necessary to produce a firm, non-tacky surface is recorded. Room temperature should be noted.

Physical tests

The following tests are conducted on the dry coating, after paint has been allowed to dry for a period of 72 hours at room temperature. These tests are identical to those performed in the analysis of hot-dip coatings, and the manner of reporting results the same.

Pliability test at room temperature.

Sag test (3 hours at 140°F).

Cold test (24 hours at 32°F).

Acid test (48 hours in 5 percent (by volume H_2SO_4).

Alkali test (48 hours in 20 percent NaOH).

Water test (7 days in flowing tap water).

Taste and odor test (8 hours immersion in chlorinated water).

Notes on these physical tests should be made and kept for future reference.

Panels and bolts used in the above tests are cleaned in the same manner as in testing hot-dip coatings. It is not necessary to heat them nor do panels require coating on both sides. The paint is spread

evenly on the panels, placed in a flat position, care being taken to allow no paint to flow over the side. The bolts are dipped several times and suspended by copper wire attached to the thread, so that the bolt touches no object. Thickness of the dry coating should be approximately $\frac{1}{64}$-inch.

Examination of solvent:

Color. Recorded as it appears to the eye by reflected light.

Odor. Odor is compared to that of the several commercial solvents.

Specific gravity at 60°F. Determined by Westphal Sp. Gr. Balance.

Evaporation test at room temperature. Two cubic centimeters of the sample are placed on a metal plate (3½ inches square) and time required for complete evaporation at room temperature noted. The average room temperature during the test period and also presence of any non-volatile matter should be recorded. On page 606, Abraham's "Asphalt and Allied Substances" will be found a table showing the comparative evaporating time of certain commercial solvents.

Distillation range. Method outlined on page 491, A.S.T.M. Standard Methods 1930, Part 2.

Examination of base:

Luster at room temperature.

Consistency at room temperature.

Pliability at room temperature.

Specific gravity at 77°F.

Softening point (ring and ball method).

Solubility in carbon bisulfide.

Non-mineral matter insoluble in carbon bisulfide (free carbon).

Mineral matter (ash).

Destructive distillation.

(The above tests on the base are performed in the same manner as outlined in the method of analysis of hot-dip coatings.)

Saponification value (milligram KOH per gram of material). See page 752, Abraham's "Asphalts and Allied Substances."

If desired the results can be expressed as percent of "Total Saponifiable Matter" by using any fatty oil equivalent (in grams) of 1 cc. of standard acid solution:

$$\frac{\text{cc.}^{*}\text{ of standard acid} \times 0.2877^{**} \times 100}{\text{weight of sample (grams)}} = \text{percent total saponifiable matter expressed in terms of tallow oil}$$

* Difference between titrations made before and after saponification.

** Equivalent of tallow oil (in grams) per cubic centimeter of normal acid.

Volatile matter (*5 hours at 165°C.*). This is the difference between percent "Loss on Heating" and percent of solvent, expressed as percent of volatile matter.

SUMMARY

The analysis of a hot-dip coating serves to determine the quality, composition and suitability of the bituminous material. It can be determined whether the base is asphalt, coal-tar pitch or a blend of asphalt and coal-tar pitch. If the base is asphalt, the type of asphalt may usually be recognized, although it is very difficult to differentiate between petroleum asphalts and hard native asphalts which have been fluxed with liquid to semi-solid residual oils, due to the similarity of their respective physical characteristics. The ash content determines the amount of mineral matter, although at present it is impossible to distinguish between added mineral matter and that originally present.

The "Physical Tests" are of great value in determining the adaptability of the coating. For example, a coating lacking pliability, chipping easily at low temperature or softening at summer heat could not be used satisfactorily for factory dipping, likewise, a coating lacking in acid or alkali resisting powers would not offer adequate protection. (Five percent sulphuric acid and 20 percent sodium hydroxide are used in the tests because they are presumed to represent the maximum acid and alkali soil conditions in the United States.)

The results of tests conducted on cold application coatings serve to determine whether the material is of the proper consistency, its quality, composition and adaptability, amount of saponifiable ingredients (the presence of free acid will interfere with the accuracy of this test, consequently a correction must be applied), and the amount and character of base and solvent. The coating should contain at least 60 percent base, be capable of drying to a firm and non-tacky surface within a period of 24 hours, and the solvent should evaporate completely, but not too readily.

The foregoing examples of interpretation indicate how the results of the tests on bituminous pipe coatings may be used in determining their suitability.

Attached are the tentative specifications and typical analysis of hot-dip and cold application coatings. These methods of testing and tentative specifications have been prepared with the thought that by their use, the buyers of pipe coating will be able to obtain the most

suitable material for their purpose. It is realized that the tests and specifications are far from being perfect, but it is hoped that by criticism and suggestion they may be considerably improved.

APPENDIX A

TENTATIVE SPECIFICATIONS FOR HOT APPLICATION BITUMINOUS PIPE COATINGS AS APPLIED TO STEEL PIPE FURNISHED THE WATER BOARD OF THE CITY OF DETROIT

Composition

The coating shall contain at least 90 percent by weight of asphaltic material, consisting of either a native asphalt, petroleum asphalt or an asphaltite, or well-blended combinations of these with or without the addition of flux (liquid to semi-solid petroleum residues) but the total amount of liquid petroleum oils in the coating must not exceed 25 percent by weight.

It shall not contain tars or pitches of any kind, vegetable oils, animal oils, waxy or greasy ingredients, rosin-products, nor more than 2 percent of sulfur.

It shall be perfectly homogeneous and free from free acids, water, dirt, foreign bodies, or any other matter that would tend to lower the quality of the coating.

Finely-divided mineral matter may be incorporated into the asphaltic compound, but the total amount of mineral matter in the coating must not exceed 10 percent by weight.

Physical properties

Volatile matter (5 hours at 165°C.) shall not exceed 0.5 percent by weight.

Softening point (ring and ball) shall be between 200° to 250°F.

Solubility in carbon bisulfide shall not be less than 88.0 percent by weight.

Non-mineral matter, insoluble in carbon bisulfide, shall not exceed 2.0 percent by weight.

Flask point shall not be less than 500°F.

Fire point shall not be less than 575°F.

The coating shall also possess the following properties: moderate hardness, good pliability, good durability, good ductility, great toughness, great tenacity, great adhesiveness.

It shall not undergo any deterioration or pitting when exposed to

air, water, acid soil or soil water, alkaline soil or soil water, chemical fumes, gases or any other corrosive agent that the coating is liable to come in contact with while pipe is above or beneath the ground.

It shall be impervious and remain so for an extended period of time to any of the aforementioned corrosive agents so that complete protection of the pipe is assured under all circumstances.

It shall be incapable of producing any deterioration or pitting of pipe surface to which it is applied and shall be a non-conductor of electricity.

It shall not impart any disagreeable and offensive tastes or odors to the water supply, whether it be chlorinated or unchlorinated, during its passage through the mains.

Physical characteristics

The coating shall show very little settling or precipitation in the dipping tanks, and be easily applied to pipe surface.

After application it shall set immediately upon cooling, to a firm, smooth and non-tacky surface, free from air bubbles, and of a uniform thickness of at least $\frac{1}{32}$ of an inch.

It shall form a good firm bond with and adhere tenaciously to surface of pipe without scaling or flaking off under any condition.

It shall not be susceptible to being chipped, bruised or scarred through treatment the pipe may receive during its transportation and installation.

It shall not become brittle or crack at freezing temperatures or sag or soften at temperatures of 140°F. or less.

It shall be of such character that should the surface be broken through, the coating will not accelerate corrosion.

It must be of sufficient hardness to resist soil penetration after pipe has been installed.

Appendix B

Tentative specifications for cold application bituminous pipe coatings applied to the exterior and interior of water mains laid by the city of Detroit

Composition and physical properties of coatings

It shall consist of at least 60 percent by weight of asphaltic base and not more than 40 percent by weight of volatile solvent and be of such consistency that it can be brushed on cold and adhere to pipe surface without necessitating the addition of a thinner or thickener.

It shall be perfectly homogeneous and show very little settling or precipitation of base, and contain no more than 1 percent by volume of water.

It shall be free from dirt, foreign bodies, mineral oils, soaps, or any other matter that would tend to lower the quality of the coating.

It shall dry to a smooth, firm and non-tacky surface, free from air bubbles, within a period of 24 hours and shall not show any tendency to sag to bottom of pipe during the course of drying.

It shall form a good firm bond with and adhere tenaciously to surface of pipe without peeling off.

It shall not be susceptible to chipping, bruising or scarring through treatment the pipe may receive before and during its installation, and be of sufficient hardness to resist soil penetration after pipe has been installed.

It shall be easily applied and shall form a coating of uniform thickness.

It shall not impart any disagreeable and offensive tastes or odors to the water supply, whether it be chlorinated or unchlorinated, during its passage through the mains.

Character of solvent

It may consist of either a petroleum or coal-tar distillate or a mixture of the two in any proportion, or any other volatile organic solvent that is capable of dissolving the asphaltic base and retaining it in complete suspension.

It shall be capable of complete volatilization at room temperature within a few hours, but must volatilize slow enough to permit satisfactory application of coating.

It shall not contain any non-volatile matter or corrosive liquids of any description, and be practically free from water.

Composition of asphaltic base

It may consist of either a native asphalt, petroleum asphalt or an asphaltite, or well-blended combinations of these with or without the addition of flux (liquid to semi-solid petroleum residues) but the total amount of liquid petroleum oils in the base must not exceed 25 percent by weight.

It shall not contain tars or pitches of any kind, vegetable oils, animal oils, waxy or greasy ingredients, or rosin products and be practically free from water.

It shall not contain any free acids nor more than 2 percent of sulfur.

If deemed necessary, mineral fillers (finely ground) may be incorporated into the base, but the total amount of mineral matter in the finished product must not exceed 10 percent by weight.

Physical properties of asphaltic base

Volatile matter (5 hours at 165°C.) shall not exceed 2 percent by weight.

Softening point (ring and ball method) shall be between 190 to 225°F.

Solubility in carbon bisulfide shall not be less than 88.0 percent by weight.

Non-mineral matter insoluble in carbon bisulfide shall not exceed 2 percent by weight.

Total mineral matter shall not exceed 10 percent by weight.

It shall also possess the following properties: moderate hardness, good ductility, good durability, good pliability, great toughness, great tenacity, great adhesiveness.

It shall not undergo any deterioration or pitting whatsoever when exposed to air, water, acid soil or soil water, alkaline soil or soil water, chemical fumes, gases or any other corrosive agent that it is liable to come into contact with while pipe is on the surface or under the ground.

It shall be impervious and remain so for an extended period of time to any of the aforementioned corrosive agents so that complete protection of the pipe surface is assured under all circumstances.

It shall be incapable of producing any deterioration or pitting of pipe surface to which it is applied and shall be a non-conductor of electricity.

It shall not become brittle or crack at freezing temperatures or sag or soften to any great degree at temperatures of 140°F. or below.

APPENDIX C

Typical analysis of asphalt and coal-tar base hot application coatings

	ASPHALT BASE	COAL-TAR BASE
Physical characteristics:		
Luster at room temperature	Bright	Dull
Consistency at room temperature	Moderate hard	Very hard
Pliability at room temperature	Rubbery	Very brittle
Specific gravity at 77°F	1.077	1.60
Physical tests:		
Pliability test (at room temperature)	Good	Very poor
Sag test (3 hours at 140°F.)	Good	Good
Cold test (24 hours at 32°F.)	Fair	Poor
Acid test (48 hours in 5% H_2SO_4)	Good	Good
Alkaline test (48 hours in 20% NaOH)	Good	Good
Water test (7 days in flowing tap water)	Good	Good
Taste test (8 hours in chlorinated water)	No objectionable tastes and odors imparted to water	Strong tarry taste and odor imparted to water after 8 hours contact
Thermal tests:		
Volatile matter (5 hours at 165°C.)	0.22%	0.92%
Softening point (ring and ball)	221.0°F.	175.3°F.
Flash point (open cup)	525°F.	430°F.
Chemical tests:		
Solubility in carbon bisulfide	95.20%	47.94%
Free carbon	0.71	13.85
Mineral matter	4.09	38.21
Destructive distillation:		
Temperature range	150°–300°C.	300°C. max.
Distillation time	30 minutes	30 minutes
Water	Trace	Trace
Distillate	38.9%	No liquid distillate
Nature of distillate	Non-volatile asphaltic and petroleum oils	Solid crystals of coal-tar compounds

Nature of coating

ASPHALT	COAL-TAR
An asphaltic composition resembling the properties of a native asphalt or a blend of hard native asphalt and soft petroleum asphalt	A coal-tar pitch, incorporated with 38 percent mineral matter

APPENDIX D

Typical analysis of asphalt-base cold application coatings

	PAINT	VARNISH
Analysis of paint:		
Consistency at room temperature	Liquid	Liquid
Water	Trace	Trace
*Loss on heating (5 hours at 165°C.)	37.5% by weight	47.0%
Base (by distillation)	63.1% by weight	53.4%
Solvent (by distillation)	36.9% by weight	46.6%
†Drying test at room temperature	22 hours	23 hours
Physical tests (applied to coating after 72 hours drying at room temperature):		
Pliability test (at room temperature)	Good	Poor
Sag test (3 hours at 140°F.)	Good	Very poor
Cold test (24 hours at 32°F.)	Good	Poor
Acid test (48 hours in 5% H_2SO_4)	Good	Fair
Alkali test (48 hours in 20% NaOH)	Good	Fair
Water test (7 days in flowing tap water)	Good	Good
Taste and odor (8 hours in chlorinated water)	No objectionable taste or odors imparted to water	Strong oily taste and pronounced oily odor imparted to water after 8 hours contact
Examination of solvent:		
Color	Water-white	Water-white
Odor	Similar to xylol	Similar to kerosene
Specific gravity at 60°F.	0.8660	0.7740
Evaporation test at room temperature	60 minutes	105 minutes
Distillation range	131°–154°C.	106°–213°C.

* Solvent plus volatile matter present in base.

† Time required to produce a firm, non-tacky surface.

Nature of solvent

PAINT	VARNISH
A coal-tar distillate resembling the properties of xylol or a mixture of xylol and solvent naphtha	A petroleum distillate, resembling the properties of that grade of petroleum naphtha commercially known as turps. substitute

Nature of solvent—Concluded

	PAINT	VARNISH
Examination of base:		
Luster at room temperature	Bright	Bright and glossy
Consistency at room temperature	Moderate soft	Hard
Pliability at room temperature	Very pliable	Brittle
Specific gravity at 77°F	1.069	1.021
Softening point (ring and ball)	187.7°F.	177.8°F.
Solubility in carbon bisulfide	94.62%	99.87%
Free carbon	0.73	0.13
Mineral matter	4.65	None
Total saponifiable matter	None	*17.5%
Volatile matter	0.6%	0.4%

* In terms of tallow oil.

(In the case of the bituminous varnish, a hard brittle film formed over the surface of base from "Loss on Heating" test, indicating the presence of saponifiable ingredients.)

Nature of base

PAINT	VARNISH
An asphaltic composition, apparently a native asphalt, or a hard native asphalt blended with a soft petroleum asphalt	An asphaltic composition, apparently a petroleum asphalt to which has been added approximately 20 percent of drying oil or fat

DISCUSSION

EVAN RINEHART (Johns-Manville Corporation, New York, N. Y.): The merit of the paper by Messrs. Wallace and Parks lies not only in that it clarifies the causes of corrosion, but also that it offers a wealth of valuable data for guarding against corrosion. My comments are offered with the hope that the paper stimulates the interest that the subject deserves.

It may not be generally known that the Bureau of Standards (Logan) has had in progress for some eight years the investigation of underground corrosion and its mitigation and that this has been augmented in recent years by fellowships in the subject established separately by the American Petroleum Institute and the American Gas Association. In these tests both nipples and sections of main trunk lines were treated with a number of protective methods and compared with adjacent bare pipe.

It is from their conclusions, and those of our company Research Department and from continual contact with protection of underground pipe, for a number of years, that the following is drawn.

My reaction is that the paper allows the major objectives of pipe protection—viz. sustained impermeability and sustained electrical resistance to be overshadowed by purely mechanical features. Imperviousness is a relative term, and with bitumens moisture absorption ranges from 0.5 percent in 300 days to 15 percent. Moreover Ewing shows the differences in permeability curves.

Would it not be better first to assure ourselves that the coating had a negligible moisture absorption property (say not over 1 percent in 300 days submersion) and for the required electrical resistance (say ten microohms in salt water—under 6 volts—10 days) and from there determine its suitability from a mechanical standpoint? Regardless of its applicability or strength, if a coating does not give sustained waterproofing and electrical resistance, it will not protect pipe exposed to corrosive influences.

In waterproofing a subway, a roof or subgrade pit we depend on the bitumen for the sealing, but support it with felt or fabric and do not expect the bitumen to do everything. Both the American Gas Association and the American Petroleum Institute point out the necessity of a reinforcing or shielding wrapper. Most coating manufactures recommend it and few gas or oil lines are coated without a wrapper.

Referring to "stability" P2 I would suggest adding; "And to long exposure to the pressure and deforming action of the soil; the pressing, squeezing, and adhesive effect that comes with every seasonal change in soil, moisture and temperature. This "soil stress" has been emphasized by Dr. Scott (A.P.I.) and Dr. Ewing (A.G.A.).

Referring, also, to the definition given of an ideal pipe coating, I feel that sustained service underground, which is really what we are after, is subordinated to ease of handling before burial. For example, an oxidized bituminous coating might meet the outline requirement and yet the weight of the earth (plus that of the filled pipes) would result in penetration of hard clods on the pipe bottom and the thickness would not prevent ultimate distortion and rupture of the coating at the pipe shoulder.

From the mechanical standpoint, why not consider the condition under which the pipe coating must serve for 20–30–50 years and, by fluxing or by whitewashing with reasonable care in handling, guard against the temporary solar, atmospheric and transporting conditions?

Consider (say) 48-inch steel main under a heavy backfill—what must its protection meet?

First, it must give sustained moisture-proofing with the accompanying high electrical resistance. To do so, it must be sufficiently firm to withstand clod or rock penetration under a weight pressure of possibly 25 pounds per square inch. It must resist the pulling action of the soil with seasonal drying. It must follow the pipe expansion and contraction of possibly 5 inches to 1000 feet. Manifestly it must be immune to soil chemicals and moisture.

If the pipe surface has been properly cleaned and primed the adhesion of the coating designed or fluxed for the temperature condition will be in excess of requirement.

The statement of the authors that practically all new steel mains are coated with asphalt-base materials would seem to refer only to water pipes. From a tonnage or a surface standpoint, the past five years have seen a considerably greater quantity of coal tar materials used—over ten thousand miles of gas line and quite a few water lines.

The statement on the superiority of native over petroleum asphalt is open to argument. Roofing manufacturers recognize the lack of uniformity, from a standpoint of purity, in native asphalt and the frequent presence of organic matter. Moreover, a custom of using a solvent to melt down means an ultimate high moisture absorption. It would appear that a vacuum distilled, non-blown, asphaltic pitch is much superior.

The same page states "Their (petroleum asphalts) quality is improved by blowing air through them, etc. is highly questionable. The adaptability to conform—sensibility is improved, but the eventual value as a protective coating is materially reduced because of the resultant high moisture absorption.

In the comparison made in the paper between asphaltic and coal tar coatings the ultimate objective seemed to be neglected. If we admit, as the paper states, that coal tar base coatings are more resistant to soil and soil water, and if we consider the greater compressive strength and resistance to soil stresses of the coal tar enamels, their superiority for sustained service would seem evident.

The sag at extreme summer heat is less than with asphalt and hundreds of miles of coated and wrapped tight (using tar base materials) have been successfully transported from mill to site. I believe that the General Paint Company, with 6 plants for mill wrapping, would agree that a considerable proportion of their business is with coal tar materials.

The ductility requirement for installed pipe is not severe for a good coal tar enamel. Generally 70°F. would cover the spread before laying and 40° the later ground temperature changes. An enamel that will stand pipe distortion of 10 percent of the diameter (as it should) has more than sufficient ductility for any subsequent underground pipe movement.

The question of contamination in the paper refers, of course, only to the interior lining, but the same paragraph apparently includes exterior coating, in so far as application is concerned. Considerable coal tar enamel has been applied under fairly low temperatures, satisfactorily, without any undue haste in laying. Also several gas companies coat and wrap in the summer, store and ship out to jobs during the winter, with temperatures ranging down to 15°. It is simply a matter of modifying the manufacturing formula or a field fluxing for the lowest temperature to be met.

Under very low temperature conditions no coating should be applied A pitch, an asphalt, or anything else that was sufficiently fluid would be ruptured or thinned during the ensuing summer. We do not agree that coal tar enamel must or should be applied at the site, based on considerable satisfactory experience with mill and yard wrapping. In many cases, the more controllable conditions lend favor to coating and wrapping in the pipe shop.

This is particularly true where questionable weather conditions are forecasted and where it might be difficult to guard against priming over wet pipe in the field or coating over wet primer. On the other hand many thousands of miles of pipe have been treated successfully in the field with coal tar enamel and asbestos felt wrapped with field machines.

In connection with "dipping" of the heavier coatings, I should like to point out the difficulty of maintaining uniform temperatures throughout the tank, the resultant differences in thickness and the probability of hidden air or gas bubbles which break open later when the pipe is exposed to ground temperatures.

For these reasons we much prefer a rotational continuous or a lathe type machine or "ragging" in the field in conjunction with a field wrapping machine. Also, a coating that admits of dipping to any thickness will invariably "ripple" when the pipe is exposed to moderate sun temperatures, with a service (Hazen and Williams) coefficient of 135 or less instead of the sustained 150 or more that is procurable with a spun enamel.

The idea given in the paper on the unsuitability of cold coatings is

borne out by the A.P.I. Research. In virtually every location it was noted that more corrosion occurred under the "cold" coating than on adjoining bare pipe, due to the high moisture absorption that comes with the evaporation of the solvent. Ease of application is certainly unimportant in comparison with service desired.

TESTING OF BITUMINOUS COATINGS

In general, the tests outline seem to me to be more academic than practical. The two fundamental requirements—impermeability and electrical resistance—are omitted and considerable space is given to items of little bearing. Pliability calls for bending a coated panel over a $\frac{1}{4}$-inch rod. A coating so pliable would undoubtedly be punctured by clod pressure with eventual pitting of the pipe.

We believe the sag test should be 6 hours, instead of 3, to meet certain field conditions. We suggest the Ewing-Scott potassium ferricyanide testing of the panels subjected to the acid, alkali and water test.

For laboratory or field samples, most coating research has abandoned panels in favor of pipe nipples, the larger the more conclusive. The preparation of the samples, as outlined, has no bearing except for testing dips, which are never used on the two to five thousand miles of oil and gas lines, and which we believe will be replaced by machine coating.

For either a coal-tar or an asphaltic enamel, the pipe or test piece should be cleaned, primed and not heated before coating. We find after considerable trials, that the resultant bond is more uniform and stronger than heating the pipe.

Further, we think field tests should be on the completed protection, i.e., a coated and wrapped pipe sample. Otherwise very misleading data will be accumulated insofar as forecasting performance on the line.

The Thermal Tests, should incorporate a "change in melting or softening point" with heating. In practice, large heating kettles are used that may serve for three hours. Obviously, if such heating produces, say, 20° rise in softening point, the coating will not be as uniform, in place, as one in which the heating gives only a 2° rise. This may be of importance if low temperatures are to be met.

The "Testing of Bituminous Paints"—also omits "moisture absorption" and/or "electrical resistance," fundamental requirements in any coating, and the essential points of weakness of any cold bituminous paint. Their ease of application is unimportant in con-

sidering lack of protection they afford. (Refer to A.P.I.—A.G.A. reports.) While we have had for many years cold coatings that are excellent for certain purposes, we certainly do not recommend or sell them for underground pipe protection.

The field test mentioned might be misleading considering the widely different severity of soil within a very short distance. (Refer Logan Bureau of Standards & Gill), the variation in moisture content, from place to place and seasonally, all as borne out by any Shepherd Resistivity Rod or Corfield test, and the fact that the sample may be anodic if near buried rusty steel or copper, or cathodic, if near zinc or other structures.

The principal defect of plate for field testing, however, is that it gives no information on the resistance to soil stress of the coating when applied to a buried pipe. Dr. Scott emphasizes the major problem of keeping the coating on the pipe, Dr. Ewing points out that soil stresses prevent satisfactory performance of many coatings otherwise suitable.

Do we not, after all, want information on the essential requirements of a protection and its suitability under service conditions?

ESSENTIAL REQUIREMENTS TESTS

(a) Moisture absorption—cube in water.

(b) Same plus electrical resistance—treated nipple in salt water, with connections to 6 volt battery (Ewing) and same in box of wetted soil 6 volts (Ewing).

(c) Chemical and thermal tests, as given by Wallace and Parks, plus "Change in M.P. with 3 hours heating," acid, alkali, water, taste tests as paper outlined.

(d) Sag test lengthened to 6 hours—cold test at lowest temperature expected.

(e) Electrical resistance under changes in temperature and pressure (Proctor, L. A.).

(f) Test for bond—knife test or weight at right angles to two bonded surfaces.

SUITABILITY TESTS OF COMPLETE PROTECTION ON PIPE OF SUBSTANTIAL DIAMETER

(e) Freedom from pinholes or air or gas bubbles, using interrupted spark gap detector (J–M) or potassium ferricyanide with pad (Ewing-Scott).

(f) Elasticity—by distorting a ring of treated pipe to 90 per cent of nominal diameter.

(g) Brittleness—by dropping steel ball (U. S.) or by guillotine (J–M) set to maximum backfill.

(h) Soil stress resistance—by subjecting treated pipe to alternate wetting and drying of (Bentonite) clay, and (2) by impressing cube weighted to 25 pounds per square inch at highest expected earth temperature and (3) by Barrett deformation test.

(i) Resistance to abrasion and movement of buried pipe—by drag test.

The specifications, as drawn, are primarily for dipping rather than for mechanical application. However, my reaction is that they are too general to insure satisfactory performance. The composition as shown could be met by a coating that would not pass a reasonable (0.70 mm., 90 hours 77°) deformation test, nor follow the "squatting" of large diameter pipe, or resist soil stresses. However, again I feel that the most serious omission is that of the fundamental requirements of moisture absorption and electrical resistance, in the way of definite limitations.

For summarizing this discussion, I feel that too much stress is laid on features involved prior to burial and too little on matters affecting sustained protection for the years of expected service.

I should like to point out that, with the wealth of data available, it is possible to determine requirements from both waterproofing and mechanical suitability standpoints. The thought is offered that the purchases would fare better if he drew his specifications along the line of requirements rather than to merely follow physical or chemical characteristics. For his final consideration the engineer can augment such requirement specification with performance history.

I appreciate the opportunity afforded to discuss this paper and hope that my jaundiced eye, that of the manufacturer, has not precluded an engineering analysis of a highly valuable paper.

PROMISCUOUS ELECTRIC GROUNDING ON WATER SERVICE PIPES AND MAINS

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Papers and discussions relating to electrolysis and to the subject of grounding of electrical equipment of various kinds to water pipes and other metallic structures have nearly always included a statement to the effect that any alternating current passing along a water service pipe will not cause any damage either to pipe or to the water itself. One or two references in literature have described rather unusual cases where water service pipes have actually been disintegrated producing total failure. Damage by stray direct current where it leaves water mains for earth is well established, but little or no information seems to be available on other possible effects of such currents or of alternating currents on the water itself. The use of alternating current is quite general and it is becoming more common all the time, so that if it has any detrimental effects no time should be lost by the waterworks fraternity in making the necessary experiments and studies to ascertain corrective measures.

By way of explanation of the terms used in this paper an "electrolytic cell" is made of two "electrodes," usually metallic, partially immersed in a liquid called the "electrolyte." The general arrangement is similar to a storage battery, except that no current can be obtained from it after the charging current is shut off. There are always two "electrodes," one where the positive current enters the cell known as the "anode" and the other where it leaves the cell known as the "cathode." Establishing a flow of current through the cell produces a series of chemical reactions in the electrolyte and perhaps disintegration of the "anode." The action which takes place with direct current is known as "electrolysis." To waterworks people, the term means corrosion of mains and services by stray

railway currents. Where alternating current is applied, a different series of action takes place to a greater or lesser degree and this will be called "electrolytic action."

The flow of electricity is not unlike that of water which, when a valve is opened, flows from a higher pressure to a lower one. "Electrical potential" is, for example, such pressure measured in volts and may exist without a flow of current, just as in the case of water pressure. A "difference in potential" between two points on a water pipe definitely indicates a flow of electric current, just as a drop in pressure along a main indicates a flow of water.

Recent and continuing experience seems to show that under some conditions a flow of current, whether alternating or direct, even if of very minute amounts through a water service pipe, apparently can stimulate galvanic action between dissimilar metals causing corrosion at threads, damage to water meters, and damage to the fixtures connected or utilized in the water system.

Observations made of meters coming into the Hackensack Water Company shops, showed the presence of conical pits in the cast iron parts of all meters both in the sizes used on domestic and also industrial services. These pits were filled with carbon and in many cases deep enough to cause failure of the bottom under normal conditions of service. The bottoms were largely filled with the products of corrosion of the cast iron and these observations led to a detailed study to determine the cause. The balance of each meter was either brass or bronze in varying amounts.

A series of rough tests run with a piece of cast iron meter bottom as an "anode," and a piece of bronze and babbitt as a "cathode," with tap water as an electrolyte, showed a galvanic current between the two metals with a current density of the order of 0.100 ampere per square foot of cathode at a temperature of 78°F. The electrolyte would remain clear only a few minutes before the formation of iron salts would cause it to become cloudy. As will be indicated later, the amount of galvanic current may be greater or less depending on the conductivity of the water used.

The detrimental effect of this corrosion is a serious matter. New cast iron bottoms may be perforated within a year and a half where the conditions are such as to stimulate galvanic action. If six or seven years of service can be obtained, the meter bottom is so filled with the products of corrosion (iron oxides and other iron salts) that the capacity of the meter is reduced to a small fraction of what

it was when new. Similarly the point where registration drops off sharply is a great deal higher than when the meter is new, indicating a heavy loss in meter registration and an increase in the percentage of unaccounted for water. Small pieces of iron rust frequently cause the meter to fail to register. The consumption per service is reduced due to inadequate flow of water through the corroded meter passages. There is increased friction of the moving parts and an increased clearance due to abnormal wear. The losses to water purveyors as well as inadequate service to their customers indicate a degree of importance of galvanic action not hitherto recognized.

Small current intensities can be very active and reference might be well made to the damage caused by galvanic action[1] where a steel filter drum containing activated carbon was almost totally destroyed in a short time. Differences of potential between steel and carbon in a series of tests with carefully prepared electrodes showed only 0.210 volts.

From an electrical standpoint, a water pipe carrying electric current consists of two parallel paths, one the metallic circuit of the pipe, the other that of the water itself. The amount of current flowing in the two paths depends upon the relative conductivity of the pipe path, and the water path. Even though the water is relatively a non-conductor, it may carry an appreciable current. The conductivity of a water depends on the amount and character and concentration of dissolved salts, some salts being more active than others. Tests made in a rough way using a pair of electrodes indicated a variation of as much as 200 per cent, in galvanic current produced in various waters, used as public water supplies, in northern New Jersey. The conductivity of water, whether surface or underground, may vary appreciably at different seasons of the year.

Should decomposition of the water or of the metallic pipe occur, the flow of water in a water service pipe would be sufficiently rapid to remove any noticeable evidence of decomposition, and yet the action might be fairly rapid, inasmuch as fresh electrolyte would be more or less continuously available. There will be little polarization to slow down the rate of corrosion or decomposition.

CHARACTERISTICS OF ALTERNATING CURRENT

Alternating current distribution circuits may be of the single, two or three phase type, usually operating at a frequency of 60 cycles per

[1] Industrial and Engineering Chemistry, January, 1933.

second. This means that the alternating current oscillates or reverses in direction 60 times per second instead of flowing continuously in one direction as is the case with direct current. For this reason, it is commonly assumed that alternating current causes practically no electrolytic corrosion, since the metal removed from a pipe or metallic structure during the period when the current flows in one direction, is redeposited when the current flows in the opposite direction. Experiments have shown that alternating current at ordinary commercial frequencies does produce comparatively little electrolytic corrosion or deterioration as compared to an equivalent direct current, and in the case of iron with a 60 cycle current applied this corrosion is generally assumed to be about 1 or 2 per cent of the corrosion produced by an equivalent direct current.

From the viewpoint of electrical engineers there has been considerable discussion of the possibility of electrolysis by alternating currents. Hayden in 1907, in a paper read before the American Institute of Electrical Engineers, described a series of experiments made in Schenectady, for the purpose of determining what action might be expected from stray railway current when single phase alternating currents were proposed with current return over the rails. Many of the statements currently made in electrical circles are based on this paper, but Hayden's experiments do not meet the situation to be referred to in this paper.

In 1917 the U. S. Bureau of Standards in Technologic Paper 72, by McCollum and Ahlborn, made a study of the effect of reversal of current on corrosion of lead and iron with somewhat more emphasis on iron than on lead. Their conclusions indicated many differences with previously published conclusions. Reference was made to the fact that the extent of reversibility of electrolytic action by alternating currents depended upon the circulation of the electrolyte and the freedom of access of such substances as oxygen and carbon dioxide which might induce precipitation of insoluble forms of iron and lead salts.

In 1919, further experiments were made by the Bureau of Standards, by E. R. Shepard, to study the corrosion of lead more in detail and to amplify the experiments of McCollum and Ahlborn. Test plates were buried in soil and also submerged in tap water to which plates were applied direct currents and other currents periodically reversed as example, for 10 minutes once in every 15 minutes. The amount of corrosion noted was influenced by the current density on

the plates with a maximum value at densities not exceeding 0.001 amperes per square foot.

Studies made by immersion of lead plates in lead salts indicated a definite redeposition so that the weight of lead plates remained constant. Photographs taken of the test plates and attached to the report show the presence of long strings of redeposited lead, an entire change in the structure and a probable loss in the mechanical strength. In these tests the loss of weight was only 4 to 10 percent of that produced by an equivalent direct current. Similar tests made by immersing lead plates in tap water showed a black spongy deposit on lead plates, but the deposit was not studied further.

When an electric current is passed through tap water the water acts as an electrolyte due to the dilute solution of the several salts it contains. While it is true that tap water in a vessel, through which an electric current is passed, reaches a state of stability, a flow of tap water through the same vessel changing and renewing the electrolyte, will never reach the same state of equilibrium and the various reactions continue indefinitely as long as the current is applied and the water flows.

Under certain circumstances, with certain current densities, actual disintegration of the electrodes will occur, usually the anode, but sometimes the cathode as well. These reactions are in addition to reactions which occur within the electrolyte making the problem complex. In the case of a water service pipe, the exact reactions cannot be predicted, but it is obvious that the flow of water through the pipe, as the water serves as an electrolyte, must upset the equilibrium and increase the effects of electrolytic action either on the water or the pipe which contains it. Any change in current strength or in the direction of flow of current will act in a similar manner.

Developments in the electrical field over a period of years have shown that certain oxides of certain metals and the alloys of these metals, have the power of rectification of an alternating current, changing it into a series of direct current impulses, thus eliminating the reversal in the direction of flow, and producing electrolysis in the same way as direct current. While the authors do not hold any brief for this theory, it is nevertheless worthy of consideration and investigation when the action of minute currents is considered.

GROUNDING OF ELECTRICAL CIRCUITS

Protective grounding of electrical circuits of various kinds is sometimes provided for direct current systems and generally used

with alternating current systems. In general, two types of grounds are used, one made by burying sheets of copper or other metals surrounding them with charcoal and salt or by driving copper coated iron pipes into the soil; the other by attaching the ground wires to metallic structures of underground systems such as water and gas pipes. The effectiveness of the driven or buried ground is limited by the resistance of the soil and the contact resistance between the ground rod and the earth so that this had led to the common use of a pipe system where available.

The National Electrical Code provides that grounds shall be made to metallically continuous water pipe systems, to be attached to any water service outside of the water meter or if it is necessary to make the connection inside the water meter, that a permanent shunt or jumper be provided around the meter. The intent of this provision to prevent an accidental opening of the circuit by the removal of the meter, thereby preventing discontinuance of the protection afforded by the ground as well as to prevent shocks to anyone removing the water meter. No current is supposed to flow regularly through such a ground for as its name indicates, it is intended to be "protective." Attachment of a ground inside of the building simply increases the length of pipe path over which any current must travel and therefore affords a greater chance for the current to act harmfully on the pipe and on the water.

AMOUNTS OF CURRENT FLOWING IN WATER SERVICE PIPES

Aside from the electrolysis surveys made in connection with the stray railway current problem, little thought is generally given to the other possible stray current problems. A complaint to an electric utility regarding current flow over a ground wire may result in a cursory test using an ordinary volt meter, which may or may not be followed by a report, which will indicate no current flow except in the most unusual circumstances. It must be realized that a current of one ampere flowing through 100 feet of copper tubing, $\frac{3}{4}$-inch diameter, with $\frac{1}{16}$-inch wall, would produce a drop in potential of .006 volts. As already referred to, the amount of electrolytic action or decomposition produced is a function of the current or of the amount of current in relation to the area of the surface from which the current enters or leaves, as in any electrolytic cell. There is probably an optimum value at which the maximum action on the electrolyte or the maximum destruction of electrodes will take place. Temperature and many other factors doubtless have an

effect. Current densities capable of producing electrolytic action or decomposition are therefore exceedingly low and any study of currents must be made with the ammeters and voltmeters with special ranges to read in thousandths of an ampere or volt. Such instruments are more accurately known as milliammeters or millivoltmeters.

Direct currents of low intensity and small differences of potentials can be easily measured as are also small differences in potential, but measurement of small alternating currents or potentials represents more of a problem. Furthermore, both alternating and direct current are frequently present on the same water service. Further analysis only will indicate the true situation. An equipment, developed by one of the authors which is capable of determining differences of potential and current strength of both types of current, amperes as well as volts, has been used, but this will not be described in detail at this time. An additional complication when water meter or ground wires are disconnected for the insertion of test instruments, the electrical current conditions may be changed and the current distribution may be altered accordingly.

QUALITY OF WATER

During the past three years the authors have had opportunity of inspecting a number of complaints of unsatisfactory quality of tap water throughout the territory supplied by the Hackensack Water Company. Records of complaints made to its Central Service Bureau, where all complaints received in the Company are filed, are accurate and complete and much of the information herewith presented is available only through the maintenance of careful records of every complaint, or unusual service conditions of any kind. Investigations made by the authors in the particular cases to be cited have indicated that the water served to adjoining buildings was satisfactory in quality in every respect, but that the water delivered at the premises where the complaint was made, varied in character, sometimes good and at other times having an alleged metallic taste, musty or moldy odor, astringent taste, sediment and other unfavorable characteristics. In a few cases illness, mostly stomach disturbances in young children or adults, has also been alleged.

Dissolved copper

In four cases intense dezincification of brass pipe has resulted in failure of the pipe apparently accelerated by a flow of current. In

two cases, including one where dezincification occurred, copper was detected in tap water coming from brass pipe. Electrical tests have not been made in all of these cases, but at one of the locations where dezincification took place stray railway current was flowing into the building over the water service pipe and on the electric ground wire and most of the current left the building by way of the gas pipes. An average of 0.050 ampere direct current was found with no indicated presence of alternating current. In the vicinity of a gas hot water heater where the dezincification and total failure within six months occurred, constant direct current potentials of the order of 0.010 to 0.020 volt were detected, perhaps due in part to the thermal effect.

In another city not supplied by this Company, copper was detected in samples of hot and cold water from the kitchen tap to the extent of 0.5 to 1.0 p.p.m. It was found that this was apparently due to defects in the wiring of an electric refrigerator. Unfortunately full data on the complaint are not available. Copper to this amount caused staining of wash cloths and a distinct blue or green stain on a white enamel sink.

In another case, on our system, where brass pipe was used, water drawn into a bathtub showed a decided greenish or bluish tint, especially when water was drawn at night. Disconnecting a radio ground where a difference in potential of 0.001 volt between the radio and water service, as found at a later test, seemed to eliminate the green or blue color but subsequent tests indicated other very objectionable electrical conditions, but apparently these did not produce further disintegration of the brass pipe as judged by lack of further color formation, the current leaving the building by other paths of less resistance than the water pipe.

Tastes and odors

Investigation of tastes and odors in tap water at certain premises were made endeavoring to eliminate one possible cause after another. The presence of taste and odor would not occur uniformly throughout the day, but would be more or less noticeable at certain fairly well defined hours. In each case, where trouble was finally attributed to electrical currents, ground wires from electric light or power lines, from four-party telephone lines, radios or some other electrical equipment, were found attached to the water service piping within the building perhaps as much as 50 feet from the water meter or the point at which the water service enters the earth. In one case, where

electric current was not available for lighting, a storage battery radio was grounded to the hot water heating system, and therefore connected with the water service. Removal of the radio ground eliminated the trouble. An examination of the Empire meter set on these premises indicated appreciable electrolysis of the screen. Another case can be cited where a radio grounded to a brass water pipe used to supply a continuous stream of water to a small aquarium caused the death of two out of three gold fish. No tests for copper were made. Removal of the ground and treatment of the one remaining fish prevented further trouble and other fish subsequently added to the tank remained healthy. At these premises but at another location in the house, a radio was at one time grounded to a metal plate in the bottom of a fish tank and the water became cloudy and fish died. Apparently here a circuit was established through the aquarium and the drainage system into earth.

Complaints have been received at one location of rusty and bad tasting water over a period of two years. Flushing or other remedies had no permanent effect. Eventually the appearance of a greenish color and an objectionable taste led to an electrical test on the brass water service pipe to this building and also the ground wires. These tests showed 3.3 amperes direct current flowing into the building on the water service and from 1.2 to 1.6 amperes of alternating current flowing between the water service pipe and the ground wires.

Effect on lead service

One case has come to our attention where a precipitate or floc in the cold water occurs several times during the day and apparently the water at this time when boiled and used for making coffee produces a slight taste in the coffee. It is further alleged that drinking of a cup of coffee containing some of this sediment produced almost immediate vomiting. While this probably can be discounted, the physical characteristics of the tap water were poor. A ground wire from a 3 wire A. C. power circuit supplying two electric refrigeration machines was connected to a lead water service outside the meter, but the meter was 30 feet from where the lead service first entered earth, and any current would have to travel this distance through the service tap. A test for lead made on water drawn from the tap showed 0.06 p.p.m. An analysis of sediment from several quarts of boiled water failed to show any tests for lead. During the month

that this complaint was under observation, the maximum rate of flow through the tap apparently increased indicating that the sediment discharged apparently represented deposits on the inside of the lead service. Subsequent tests indicated an alternating current of 2.3 amperes flowing out over the service accompanied by 0.08 ampere of direct current, apparently stray railway current. The alternating current flowed only when the refrigeration equipment was in operation. Water drawn following the operation of the refrigeration equipment apparently contained more sediment than water drawn at other times.

Effect on iron service pipe

Investigation of one complaint of bad taste in tap water indicated that the water had a taste of strong tea, produced a very heavy deposition of iron in toilet bowls and in lavatories although the water in the mains showed only 0.1 p.p.m. of iron. This tap water showed no difference in pH, as compared with water from other taps in the vicinity. The condition was worst in the morning and late afternoon hours and the claim was further made that the water, taken on an empty stomach, would produce a severe case of cramps. In this case the meter was in front of the building and there was about 150 feet of $\frac{3}{4}$-inch iron pipe extending to the rear, the lavatory being about 75 feet from the street. Power was received through an underground electric service, terminating in the rear of the building in a room where an oil burner was located, the boiler of which was connected to the water pipe. The electrical equipment at this point was all grounded on the water piping. Tests made by removing the water meter showed a difference of potential across the meter gap of from 0.2 to 3 volts. Closing this gap through an ammeter showed an average current flow of 0.036 ampere direct current flowing in over the water service and 0.11 ampere alternating current. In this locality material changes in railway load conditions are likely at different times of day so that in the morning and evening at heavier load periods, the current might be larger than measured.

EFFECT OF JOINTING MATERIAL ON CAST IRON MAINS

In the fall of 1929 in Spring Valley, New York, served by a subsidiary company, complaints were made of very disagreeable taste and odor in the water supplied to about five residents on two streets, but other residents in the immediate vicinity supplied by the

same feeder main had water of satisfactory quality. The taste was strong metallic with a reminder of rubber and the odor could perhaps best be illustrated by that produced by a decomposition of some dead animal in a body of water. Flushing and other remedies produced no results. Accidentally it was found that this was due to a defective insulation on an underground service and which permitted considerable alternating current to flow from this service through earth and about 400 feet of 6-inch water main to a brass water service on which there was a ground connection from a three wire electric service. The primary fuse of the transformer which was of 15 amperes capacity, did not blow because this would have required a secondary current in excess of 150 amperes. The soil in the neighborhood of the defective underground service was dry gravel but periodic tests made on the lightning arresters showed fairly good conductivity.

In the distance of 400 feet all the joints in the water main were lead except three leadite joints installed three months previously. The resistance of these leadite joints apparently prevented a heavy enough flow of current to blow the fuses. The resistance introduced by the leadite joints caused heating or arcing between the cast iron pipes which in turn burned the oakum and produced the metallic and rubbery taste and the dead animal odor. The condition stopped immediately when the defective electric service was disconnected.

In a house, under construction, in the neighborhood, shocks were obtained whenever a water service cock in the basement was opened. In this case the floor was damp earth, not yet having been concreted. Whenever a person in any of the houses supplied in that neighborhood came in contact with the water service and a drain pipe, concreted cellar floor or any well grounded structure, that person would have received considerable electric shock.

REMARKS

The examples cited in the foregoing are admittedly rather scattered and inconclusive, but they indicate that there is a need for further study and investigation of possible electrolysis or electrolytic action and a harmful effect causing corrosion, color, odor and taste, all arising from the presence of stray alternating and direct current on water pipes. The extent and severity of the damage to meters and house piping and the deleterious effects upon the quality of the water in the territory referred to, are certainly serious enough to warrant consideration, and it is the purpose of this paper to draw

attention to this problem so that the general experience and data may be accumulated by the Association. It is, therefore, suggested that any or all information or experience with problems of this or of a similar nature be reported to the association for study and correlation.

DISCUSSION

CHARLES F. MEYERHERM: The problem which Mr. Hill has presented is one which should interest every water works operator and it is hoped that its discussion will bring forth information and details concerning similar experiences by other water works operators. While it is too early to express reliable opinions or conclusions concerning the exact manner in which the electric current produces the corrosion or deterioration of pipes or water meters and sets up the objectionable colors, odors or tastes in the water itself, there are ample reasons for believing that such action is taking place and that it may be a serious operating and economic problem at least in some locations or with some water supplies.

Most electrical men will scoff at the idea that flow of electric current on a pipe can have any harmful effect on the metal of the pipe or the water within it, and the writer felt the same way about it when the matter first came up several years ago. Actual contact with the problem in the field has however completely altered the first impression, and I now feel that there is enough to it to justify the careful consideration of every water works man.

The relation between stray electric current and the corrosion, deterioration, color, taste and odor effects is not an obvious one and it is questionable whether the average water works or electrical man would associate the two unless his attention was called to it or he happened on an unusually aggravated case. The electrical tests as well as the chemical analyses involved are not simple and the absence of definite indications of stray current or of chemical disturbance of the character or quality of the water cannot be taken as proof of immunity, unless such tests are made with highly sensitive equipment and methods by careful and conscientious investigators. Such tests will probably only be undertaken by a few of the largest or most vitally interested water works systems, but that does not mean that general experience data from as many sources as possible will not be extremely useful to those who are making or will make a detailed study of the problem.

It is therefore suggested that all who have had or who may encounter corrosion, deterioration, color, odor or taste troubles of the type referred to by Mr. Hill, send a brief statement of the trouble and as much pertinent data as they may have available to the Association headquarters or to Mr. Hill for correlation, study and analysis.

As representatives of the American Water Works Association on the Article 9 Sub-committee of the Electrical Committee which prepares the rules for grounding electrical circuits, Mr. Hill and the writer should have in hand all available information on the subject in order to properly present the water works side of the grounding problem. We would therefore request the constructive coöperation of the members of the Association in this problem which may affect the entire water works industry as well as in the matter of general experience with grounding.

SOME MODERN METHODS OF COATING AND LINING PIPE

By Linden Stuart

(President, Wailes Dove-Hermiston Corporation, New York, N. Y.)

LINING CAST IRON PIPE

This method of application consists of priming the pipe while hot by the regular tar dip method. After the pipes have been dipped and have cooled off they are then placed in a turning rig and revolved at a speed best suited to evenly distribute the hot Bitumastic Enamel on the interior surface. The speed varies considerably with the diameter of the pipe.

The Bitumastic Enamel is applied by inserting into the pipe a trough carrying the required amount of Enamel. When the pipe has reached the suitable speed the trough is turned over, thus depositing the coating on the pipe surfaces.

The whole operation of lining is performed in a very short time; the Bitumastic Enamel cools and hardens very quickly, and, therefore, the pipe may be removed from the rig in approximately five minutes from the time that it is placed therein. The pipe may then be immediately loaded for shipment.

The result of this operation gives a coating on the interior surface of the pipe of about $\frac{3}{32}$-inch thick, which is very glossy and smooth, having all the appearance of black glass.

While this operation appears simple to the casual observer, it is absolutely necessary, in order to obtain the best results, that every step of the operation be carefully checked and supervised. For example, detailed specifications are issued governing the composition of the tar priming coat. Periodic tests of the tar dip are taken and corrections made to insure that the composition remains constant as the hot pipes are being dipped in same. Hot pipes cause evaporation of the more volatile substances of the dip, and, therefore, corrections must be made.

The pipes must be heated to within the specified temperatures in order to prevent the prime coating from being too hard or too soft.

It is also necessary that the Bitumastic Enamel be heated to and applied at the correct temperature.

A similar method for lining cast iron pipe with Bitumastic Enamel has been worked out for a portable rolling rig in a storage yard. By this method the pipes are prime-coated with Bitumastic Solution which is applied cold and requires about 5 to 12 hours to dry before the Enamel is applied. This method has been adopted by several water departments and seems to be gaining favor, as it permits the relining of old pipes, and pipes that are going to be put in a line for short extensions or repairs.

To insure the minimum effect of temperature changes on the lining, the outside of all pipes are always given a heavy coat of whitewash, and also the inside of the pipes back from the ends for a distance of several feet.

Where lead joints are used, it is desirable to keep the temperature of the lead under 800° Fahr., and in cases of the large diameter pipes, it has been found desirable to put a pad of clay under the pouring gate, so that the stream of hot lead does not strike directly on one spot of the pipe.

Considerable pipe, lined with Bitumastic Enamel, applied by this method, is now in use in various parts of the country, the result of which is that considerable knowledge and experience have been gained, both as to the advantages and disadvantages. The advantages will be dealt with later. The disadvantages might be stated as follows: The well-known susceptibility of coal-tar pitches to temperature changes, causing softening and flowing at high temperatures, and checking and cracking at low temperatures, applies to some extent to Bitumastic Enamel. However, from years of experience with this material in various climates, a way has been found to combat these conditions up to a limited extent. Where extremely warm or extremely cold weather is to be expected, the Bitumastic Enamel is conditioned at the time of application by the use of a fluxing oil. If the coating is conditioned at the time of application for temperatures only as low as 30° Fahr., and the pipes before laying are exposed to temperatures around zero, some cracking of the Enamel coating will occur. The Enamel coating will sag if the coating is conditioned for low temperatures and the pipes are not laid until mid summer, when they will encounter high temperatures. This condition, however, has been overcome, and it is gratifying to report that, based on the results of certain long-time exposure tests, this baffling problem has now been solved.

The composition of cast iron pipe occasionally has a very peculiar effect on the Enamel lining immediately after application. The same enamel material out of the same drum will blister on some pipe and not on others. This condition, however, has been eliminated to a very great extent by slight changes in foundry practice.

LINING OF STEEL PIPE

Up to the present time, the procedure as to application is quite similar to that described for cast iron pipe, except that in the case of steel the surfaces are primed by a cold application of Bitumastic Solution, instead of the heating and dipping method. The adhesion of the Bitumastic Enamel lining, applied by this method, has been several times questioned by engineers, and, therefore, it should be stated here that on a recent line 30-inches in diameter, 10 miles long, slightly less than one-half of one percent of the surfaces coated required to be touched up after the line was laid. This could not be considered as a serious defect when it is stated that the line was laid in very hilly, rugged country, and the lined pipes at times had to be snaked for thousands of feet to get them to the side of the trench.

As the method of jointing steel pipe is different from that of cast iron, it is the practice in lining the steel pipes to keep the lining back about 6 inches from the end. This permits the joints to be made up either by welding, riveting or by Dresser couplings. After the joints are made up, workmen are sent in the pipe to prime and hand-coat the uncoated surfaces. When this joint coating is done by experienced workmen, a very smooth surface can be obtained. Special care and attention are always given to this.

So far the lining of steel pipe has been conducted at a storage yard near the site of laying, and, therefore, no difficulty has been experienced as to temperature cracking or sagging, the coating being conditioned as described above to meet the various temperature conditions. On steel pipe no blistering has ever been experienced as in lining cast iron pipe.

ADVANTAGES OF LINED PIPE

The lining being of an average thickness of about $\frac{3}{32}$-inch, it is, therefore, three to four times as thick as the average heavy hot dip coating. Very much longer life may be expected from a coating of this thickness. It therefore gives assurance that a pipe line so coated will remain free from tuberculation and corrosion for many years.

The Bitumastic Enamel lining is smoother than cement lining. A higher coefficient, therefore, for the value of "C" in the Hazen & Williams formula is to be expected.

The Bitumastic lining has no effect on the water as to taste, nor does it in any way change its softness.

TABLE 1

Flow tests on Bitumastic lined pipe

LOCATION	DATE OF TEST	SIZE	LENGTH	AGE WHEN TEST WAS RUN	KIND OF PIPE	HAZEN AND WILLIAMS "C"	REPORTED IN
		in.	*feet*	*years*			
Parsippany Troy Hills Line, Pa.	1932	12	5271	New	C. I	148	Elson T. Killam, Journal A. W. W. A., October, 1932
Parsippany Troy Hills Line, Pa.	1932	12 10	5490 12263	New	C. I.	150	Elson T. Killam, Journal A. W. W. A., October, 1932
Weston, Mass.	1932	12	2340	1½	C. I.	167	Chas. W. Sherman, Jour. A. W. W. A., Feb., 1933
Alhambra, California	1932	20	2 miles	2	C. I.	158	Thos. B. Downer, Journal A. W. W. A., May, 1933
Tamaqua, Pa.	1933	30	10 miles	New	Steel	144	J. D. Carpenter; not published

As no leaching of the lining occurs, the water may remain in the pipe at the dead ends indefinitely without imparting any taste or permitting small particles of grit to accumulate in the water.

Fittings, such as bends, etc. which cannot be coated by the spinning method, are coated by a hand application, i.e., one coat of Solution and one brush coat of Enamel. This assures a continuous coating of the same kind of material with the same adhesion, throughout the entire length of the line.

The most important advantage is the high coefficient associated with the smooth, glossy lining. A brief summary of the tests run on various pipe lines is given in table 1.

These tests were run on actual pipe lines, and the effects of disturbances due to changes in grade and elevation, from bends, T's, valves and joints are reflected in the results. Many flow tests in the past have been on straight lengths of pipe with carefully made joints, and really are laboratory tests. Such ideal conditions never exist in actual practice, and an engineer, attempting to use the results of such tests, must harmonize them with the anticipated reduction in flow due to bends, etc.

A study of these tests will indicate that the coefficient "C" in Hazen & Williams formula varies from 144 to 167 on pipe of diameters from 10 to 30 inches. The age of the lines tested ranged from new to two years old. The lines tested varied considerably in length, contours, bends, and fittings as well as being of both cast iron and steel construction.

The tests, therefore, cover a wide range of conditions and uniformly indicate such a high value for the coefficient that it would seem to be perfectly safe to use a value of "C" of 140 for estimating purposes.

Naturally one of the distinct advantages of such a high coefficient is the fact that under any given set of conditions, the pipe diameter can be reduced below the size required where a lower coefficient is used. In other words, many engineers use 100 as a value for "C" in calculating pipe sizes. It is interesting to note how much the pipe diameters can be reduced where a value for "C" of 140 as against 100 is used. The comparison is as follows:

Diameters of pipe, in inches

When C = 100	When C = 140
12	10.50
20	17.55
30	26.30
48	42.10

Generally speaking, it has been found that the ability to reduce a pipe diameter, on account of the improved flow, has effected a saving sufficient to pay for the lining. Of course, where the water is pumped, there is also a considerable saving in power required, as pointed out by Downer in his paper noted above.

Bitumastic Enamel applied only $\frac{1}{32}$-inch thick, by hand brushing, has now been in continuous service on certain sections of a steel pipe line in the City of New York. A recent examination of this very thin coating gave evidence of satisfactory performance over a period of 19 years. This is an unusual record, when it is considered that the Catskill water of the New York water supply system causes very serious tuberculation. Records of like performance for almost the same period of time have been shown on other city water supply mains, as well as many hydro-electric penstocks throughout the country.

This remarkable performance was secured with a coating only $\frac{1}{32}$-inch thick. The same lining applied by this new method will be three times as thick. Engineers can, with assurance, design their lines without regard to subsequent loss of flow due to tuberculation.

Another advantage in the use of this type of lining is the high initial efficiency possible in pumping units, and its maintenance over a long period of years.

THE PROTECTION OF EXTERIOR SURFACES

The exterior coating of steel pipe has, in recent years, been receiving a great deal of attention, particularly in sections of the country where severe soil corrosion and soil distortion is encountered, and also where pipes are laid in city streets under concrete or other heavy paving.

What promises to be the most satisfactory method under all conditions is the application of a reinforced cement mortar wrapping over a coating of Bitumastic Enamel. The reinforced cement mortar coating is applied in varying thicknesses, from $\frac{1}{2}$ to 1-inch depending on the possible corrosiveness of the soil, and the diameter of the pipe.

Briefly the method of application consists of placing the pipe in a machine the same as a lathe. A traveller, carrying a mixing hopper and reels of fabric and reinforcing mesh, moves up to one end of the pipe at the start of the operations.

The wire fabric with the cheesecloth on the outside is fastened to one head of the lathe. The pipe is then revolved at a slow speed, and the cement mortar, fed from the hopper above to the wire mesh, is carried on to the revolving pipe. The outside cheesecloth fabric acts as a form or bandage to prevent the cement mortar from falling off the pipe until it has taken an initial set. While the cement

mortar is fed from the hopper it is subjected to high frequency vibration. The vibrators are also located on the steel apron or feeding table and also directly under the point where the reinforced cement mortar contacts the pipe. The result of this vibration is that a very hard, dense mortar covering is obtained.

After the pipe has been completely wrapped, the cement mortar is cut off about 6 to 8 inches from each end of the pipe. This is done while the pipe is in the machine, and to prevent spalling there is a tape wrapped on the end, leaving a very neat, workmanlike finish.

The reinforcing mesh is wrapped under tension so that it lies flat and smooth within the wrapping, and does not at any place touch the pipe. It is about one-third in from the outer surface.

Greater thicknesses than 1-inch can be secured by successive applications of wrapping while the pipe is in the machine. The cement mortar recommended consists of one part of cement to two and one-half parts of sand for ordinary purposes. This may be varied to a richer or leaner mix if desired. The pipes are taken from the machine and the covering is allowed to cure for 24 to 36 hours under ordinary weather conditions. They may then be taken to the ditch and laid.

After the pipes have been laid and the field joints made up and tested, the surfaces are coated with Priming Solution and Enamel by hand, and then a light steel form is sprung around the joint and the cement mortar poured in. High frequency vibrators are always used on the form to insure a dense mortar. Within a few hours the form may be removed, and the trench back-filled.

The advantage of such a covering will be readily appreciated. It insures perfect protection for the coating underneath, is not affected by the pulling action of the soil, and will prevent the scraping off of the coating where the pipe is in contact with rocks, cinders or other kinds of hard back-fill. It is, in itself—on account of its density—very water-proof. It is much more acid and alkali-proof than ordinary cement mortar covering that might be put on the pipe by either trowel, form or gun.

The oldest field record is of a line about three years old. This is a short section of a 44-inch diameter steel line which was covered with ½-inch of this reinforced cement mortar. This section of pipe is in the connecting line between the Hetch Hetchy system and the East Bay Municipal System, and is located in the vicinity of Newark, California. Several months ago an examination was made of the cement covering and it was found to be in perfect condition.

The longest and largest water line so far protected by this method was a 25 mile section of the Hetch Hetchy water supply system of the City and County of San Francisco. This line consisted of 56- and 66-inch diameter steel pipe. The thickness of steel was from $\frac{5}{16}$ to $\frac{1}{2}$-inch. All of the pipe was covered with $\frac{1}{2}$-inch thickness of reinforced cement mortar, with the exception of about one mile. This one-mile section was located in the very corrosive soil of the lowlands adjacent to the San Joaquin River. As this section is likely to be under water for considerable periods of time, it was covered with 2 inches of reinforced cement mortar.

This type of protection can be applied either in a storage yard near to the pipe line right-of-way, such as was done in the case of the Hetch Hetchy line, or it can be done at the plant of the pipe fabricator.

COSTS

The cost of the Bitumastic Enamel lining has usually been about the same as cement lining; that is, where the thickness of the cement is applied in accordance with the A. W. W. A. specifications.

The cost of the reinforced cement mortar covering varies with the size and length of the line, the location of the work and the specifications covering the thickness, mix, etc. Consequently, any mention of costs would be misleading.

CONCLUSION

The lining of the pipe and the covering on the outside in effect results in a new type of pipe. This pipe would be free from any pitting, corrosion and tuberculation. It will have initially, and will maintain, a greater carrying capacity than most of the pipe that is now being used.

The steel thickness need not be greater than required to carry the designed pressure with a reasonable factor of safety, and to provide sufficient rigidity. No excess steel is required to provide against corrosion. The saving in cost of the excess steel usually is sufficient to compensate for the cost of lining and wrapping.

DISCUSSION

Leslie W. Stocker (Senior Civil Engineer, Public Utilities Commission, San Francisco, Calif.): The Hetch Hetchy Aqueduct Pipe Line mentioned by Mr. Stuart extends across the San Joaquin Valley, a distance of over 47 miles. It passes through many different

kinds of ground requiring considerable variation in the type of exterior protection for the steel. A brief mention of the different types of coatings used may be of interest.

The pipe line was built in 1931 and 1932. It is from 56 to 66 inches in diameter, of steel plate $\frac{5}{16}$ to $\frac{1}{2}$-inch thick. The longitudinal seams are welded. The sections are of 30 feet laying length. The field joints are riveted, except for a short distance, where they are welded.

The entire line has an asphaltic coating inside and out, applied at the shop by dipping.

Additional protection was applied on the entire length outside, and on a short length inside, as follows:

CLASS OF COATING	LENGTH	CONTRACT PRICE PER SQ. FT.	RANGE OF PRICES IN 8 BIDS
	miles	*cents*	*cents*
Outside of pipe:			
Felt wrapping	21.85	3	3– 6
Cement mortar, ½ inch thick, wrapped on	23.37	9.7	6–13
Cement mortar, 2 inches thick, wrapped on	1.05	26.5	14–50
Concrete, 6 inches thick, poured in place	0.93	47.0	46–90
Aluminum paint	0.14	3.5	1.5– 5
Total length	47.34		
Gunite, 1 inch thick on part of the ½ inch cement mortar	0.15	20.0	
Inside of pipe:			
Gunite 1½ inch thick	0.93	40.0	14–50

All cement mortar, concrete, and gunite are reinforced with steel wire, the cost of which is included in the prices mentioned.

STUDIES PRECEDING DECISION ON COATINGS

Several years before construction, steel plates coated with different commercial paints and asphaltic coating materials were buried along the pipe line location at points where the soil and underground conditions were known to be such as to induce rapid corrosion. During preparation of specifications, these plates were dug up and their condition noted. The condition of existing pipe lines and

other underground structures in the vicinity was determined. A soil survey was made covering the entire line. Engineering literature was searched for information bearing on the effects of alkaline soils on steel, concrete, and asphaltic and coal-tar base coating materials.

The nature of the additional protection outside the asphalt, for the respective sections of the line, was determined on the basis of these investigations.

ASPHALTIC COATING

For the dipped coating, specifications were evolved for a specially blended asphaltic base material to be applied by dipping. A minimum thickness of $\frac{1}{16}$-inch was required. After dipping, each section of pipe was allowed to drain and cool for a few minutes while standing on end, and then re-dipped and immediately withdrawn from the bath. This procedure gave a tenacious, glossy coating of the required thickness, without bubbles or pinholes.

At field joints, and wherever hand coating was necessary, a priming coat of the same composition mixed with gasoline was used, and then the undiluted material brushed over it.

FELT WRAPPING

Where the preliminary studies indicated dry, non-aggressive soil conditions, the pipe was wrapped with 40-pound asphalted rag felt, applied spirally at the fabricating shop by means of the usual lathe-type machine. The felt was intended primarily to protect the asphalt against mechanical injury from the time the pipe left the shop until final settlement of the pipe and backfill in the trench, but is not expected to be permanently waterproof.

In more recent specifications, 15-pound asbestos felt is admitted as an alternative to rag felt. The manufacturers of asbestos products claim much longer life for this material as a pipe wrapping, which may not be fully justified, since vegetable fiber is used in it as a binder for the asbestos.

CEMENT MORTAR COATINGS

In soils that are slightly alkaline, or may become so under future agricultural development, the protective coat outside the asphalt is a layer of cement and sand mortar $\frac{1}{2}$-inch thick wrapped on the pipe in the manner described by Mr. Stuart, at a plant which was erected

successively at two points near the pipe line location. This plant and methods of handling the work are described in detail in Engineering News-Record, November 19, 1931. The mortar contains cement in the proportion of 12 sacks per cubic yard of mortar, which is about a 1:2 proportion. Cement giving high early strength was used. This was not required by the City, but adopted by the contractor so as to shorten the curing period, and permit early shipment of pipe from the yard to the trench. After testing the pipe, field joints were covered with collars of gunite, or of concrete poured in forms.

Cement mortar protection 2 inches thick was wrapped on in two 1-inch layers. This thickness was used where the soil was highly alkaline, and where the underground water table would be above the bottom of the pipe for long periods.

The high cement content and the vibration of the cement mortar in the course of application give a very dense product, as determined by laboratory tests for absorption. In the use of this type of coating, however, precautions should be taken to avoid opening cracks through the mortar after it leaves the wrapping machine. The steel pipe should be carefully formed at the shop, as nearly as practicable to a true circle, and after a little experience on the San Joaquin work, we required bracing the pipe to its circular form before wrapping. The bracing was left in place until the pipe was laid and enough backfill placed around it to prevent distortion. The plate should not be very cold at the time of wrapping, otherwise the stretch in the steel when under working pressure or test pressure may be sufficient to cause cracks to open in the mortar coating. This actually happened on Hetch Hetchy work, in some cases where the pipe had been wrapped in temperatures near or below freezing, without provisions for warming the steel. In such cases the cracks were filled with asphalt, or with mortar applied by hand.

CONCRETE JACKET 6 INCHES THICK; GUNITE LINING

Beneath the San Joaquin River channels and adjacent land, the pipe had to be laid at relatively great depth. On account of the relative inaccessibility of this pipe after completion, extra precautions were taken to insure its long life. A reinforced concrete jacket 6 inches thick was poured around the pipe while it was held under working pressure. Each section of this pipe had previously been lined with gunite 1½ inches thick.

ALUMINUM PAINT

Aluminum paint having an asphalt base was applied on permanently exposed sections of the pipe. It was feared that mortar might crack and fall off in such locations in the course of time, so mortar was omitted and the aluminum paint applied to the shop coating.

GUNITE COATING

This was an after-thought. Gunite coating was used in a number of scattered locations where only a few linear feet of pipe were to be covered at each point.

ERRORS AND OMISSIONS

SEVENTH EDITION—STANDARD METHODS FOR THE EXAMINATION OF WATER AND SEWAGE

The following errors and/or omissions have been noted in the first printing of the seventh edition—Standard Methods for the Examination of Water and Sewage.

1. Omissions of items in Index.
   Bile salt agar, 174
   Boiler water, 157, 72
   Carbon in sewage, 163
   Cellobiose test, 171
   Citrate test, 171
   Coli-aerogenes English procedure, 172
   Fecal and non-fecal coli-aerogenes organisms, 170
   Ferrocyanide citrate agar, 166
   Lactose broth buffered, 166
   Media, bile salt agar, 174
   Media, sulfite glucose agar, 174
   Sodium citrate test, 171
   Solids, total, 92, 162
   Sulfides in sewage, 164
   Sulfite glucose agar, 174
2. P. 50. Error in the footnote, the initials of Mr. Mathews should be E. R. not E. A.
3. P. 49. Error. A serious error results from omission of a decimal point. In Section 3 (Preparation of Iron Standards) line 4 should read "about 40 ml., add *0.5* ml. of 3N hydrochloric acid." The text now reads 5.0 not 0.5 ml. 3N HCl. The effect of this is to alter materially the results obtained by the method.
4. P. 158. Omission. During the process of editing the mss. it was agreed that the following footnote would be added to this page:
   "Investigations as yet unpublished indicate deficiencies in this method. Persons desiring to determine fluorine are cautioned to familiarize themselves with the literature on the subject after the date of this publication."
   It was unintentionally omitted and the following will be substituted in the next printing.
   "Persons interested in determination of Fluorine should refer to literature on the subject of Fluroine determination after 1932 especially to Industrial & Engineering Chemistry, Analytical Edition, Vol. 5, 1933, pp. 234 and 236."

5. P. 163. Error in bibliography, "Fairshall" should be Fairhall.
6. P. 166. Error in bibliography, "Dominik" should be Dominick.

Those possessing copies of the seventh edition are requested to enter the corrections in their copies. Further errors, when and if noted, should be brought to the attention of the undersigned promptly so that corrections can be made before the second printing.

A sentence should be added to the present "note" at the bottom of page 29. After the words "distilled water" add the sentence, "The 'stock' soap solution is approximately 9 to 10 times as strong as the 'dilute standard' soap solution."

HARRY E. JORDAN,
Box 855, Indianapolis.

ABSTRACTS OF WATER WORKS LITERATURE[1]

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

The Extent of Goiter in Hungary and Its Connection with the Iodine Content of the Drinking Water. JOHANN STRAUB. Z. Hyg. Infektionskrankh., 111: 472–9, 1930. From Chem. Abst., 25: 525, February 10, 1931. The prevalence of goiter in Hungary was not found to be related to iodine content of drinking waters.—*R. E. Thompson.*

Unanswered Questions in the Biochemistry and Geochemistry of Iodine. ROE E. REMINGTON. J. Chem. Education, 7: 2590–9, 1930. From Chem. Abst., 25: 530, February 10, 1931. Using available literature as basis for discussion, it is shown that there is need for further investigation of relation of goiter prevalence to iodine consumption. Many surveys of goiter prevalence with respect to certain conditions are inaccurate because of lack of control of diet, soil fertilization, and other factors.—*R. E. Thompson.*

Solubility of Lead in the Municipal Water of Leipzig. STICH. Pharm. Ztg., 75: 1262–3, 1930. From Chem. Abst., 25: 550, February 10, 1931. Results are given which were obtained in comparative series of experiments on solubility of lead shavings and pipe in distilled water and in water supplied in Leipzig. Results reported emphasize necessity for constant control of water coming in contact with lead.—*R. E. Thompson.*

Titrimetric Determination of Calcium and Magnesium in Drinking Water. M. E. STAS. Pharm. Weekblad, 67: 1245–59, 1930. From Chem. Abst., 25: 550, February 10, 1931. The VON LUCK and MEYER method (C. A., 23: 3037) for determining calcium and magnesium content of river water, based on precipitation of calcium as oxalate and titration with potassium permanganate and precipitation of magnesium as *o*-hydroxyquinoline salt and bromination thereof, is slightly modified for determination of calcium and magnesium in drinking water in which bicarbonate and iron are frequently present.—*R. E. Thompson.*

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[1] Vacancies on the abstracting staff occur from time to time. Members desirous of coöperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

Rapid Method of Detecting and Determining Fluorine in Mineral Waters. J. CASARES and R. CASARES. Añales soc. españ. fís. quím., **28**: 1159–62, 1930. From Chem. Abst., **25**: 550, February 10,1931. Fluorine can be readily detected in mineral waters rich in fluorine by evaporation of about 15 cc. to dryness on water bath in porcelain dish, adding a little silver sulfate and glass powder, and covering with watch glass on which hangs a drop of 1 percent barium acetate solution slightly acidified with acetic acid, formation of barium fluosilicate being observed through a microscope. Fluorine may be determined colorimetrically by adding to 100 cc. of sample in 120 cc. tube 1 cc. concentrated hydrochloric acid and, after shaking, a few drops of mixture of equal parts of 0.17 percent sodium alizarinsulfonate solution and 0.87 percent zirconium nitrate solution, comparing color developed with that with known amounts of sodium fluoride treated in same manner.—*R. E. Thompson.*

Methods for the Determination of Small Quantities of Active Chlorine in Purified Waters. S. ANSELMI and A. CALO. Ann. chim. applicata, **20**: 410–24, 1930. From Chem. Abst., **25**: 550, February 10, 1931. Review of colorimetric methods employed for determining small quantities of chlorine in water. Authors prefer *o*-tolidin method, which they find sensitive to 0.02 p.p.m. chlorine. For concentrations over 0.2 p.p.m. they recommend potassium iodide and starch and titration with sodium thiosulfate.—*R. E. Thompson.*

The Treatment of Water for Bleaching and Dyeing. C. D. BLACKWELDER. Textile Colorist, **52**: 769–70, 1930. From Chem. Abst., **25**: 597, February 10, 1931. Type of troubles which unsatisfactory water treatment may cause are briefly outlined. Importance of proper study of particular supply to be treated and of processes and chemical reactions occurring in the plant, prior to designing the plant and deciding on chemical treatment to be employed, is stressed.—*R. E. Thompson.*

The Solution Velocity of Oxygen in Water. III. SUSUMU MIYAMOTO and TETSUO KAYA. Bull. Chem. Soc. Japan, **5**: 321–5, 1930; cf. C. A., **24**: 5575. From Chem. Abst., **25**: 635, February 20, 1931. Diameter of tube through which oxygen was bubbled into sodium sulfite solution was varied from 0.23 to 0.49 centimeter, and it was found that solution velocity varied inversely as the product of diameter and velocity of rise of bubbles (which was approximately constant).—*R. E. Thompson.*

Determination of Sulfur By Means of the Turbidimeter. S. W. PARR and W. D. STALEY. Ind. Eng. Chem., Anal. Ed., **3**: 66–7, 1931. From Chem. Abst., **25**: 661, February 20, 1931. Turbidimeter is pictured and described which is suitable for control of sulfate in boiler water. Results obtained by different operators are given.—*R. E. Thompson.*

Analysis of Dilute Iodine Solutions. HERMAN A. LIEBHAFSKY. J. Am. Chem. Soc., **53**: 165–6, 1930. From Chem. Abst. **25**: 662, February 20, 1931. To solution containing from 0.13 to 0.5 mgm. of iodine add carbon tetrachloride and shake vigorously, using about 25 cc. to extract all iodine. Transfer

carbon tetrachloride solution to 500-cc. flask containing 50 cc. 1 percent potassium iodide and enough acid to make solution about 0.001 normal in hydrogen-ion. Titrate with freshly prepared 0.004 normal sodium thiosulfate until carbon tetrachloride is practically colorless on shaking, add 5 cc. starch and enough additional thiosulfate to make CCl_4 layer colorless. This combination of starch and CCl_4 endpoints is more sensitive than either alone.—*R. E. Thompson.*

Rapid Colorimetric Estimation of Iodine in Mineral Waters and Brines. L. C. CASE. Chemist Analyst, **20**: 1, 9, 1931. From Chem. Abst., **25**: 662, February 20, 1931. To sample containing from 0.10 to 0.65 milligram iodine add 20 cc. of carbon bisulfide or chloroform. Add 6 drops of sulfuric acid saturated with nitrogen trioxide and compare color that develops on shaking with set of standards.—*R. E. Thompson.*

Proposed Modification of "Oxygen Consumed" Method for Determination of Sea-Water Pollution. H. K. BENSON and J. C. HICKS, JR. Ind. Eng. Chem., Anal. Ed., **3**: 30–1, 1931. From Chem. Abst., **25**: 663, February 20, 1931. Non-concordant results between determination of organic content by biologic method and "oxygen consumed" by permanganate led to modification of technic for carrying out latter determination. Carry out digestion exactly as in standard method, then for determination of unconsumed permanganate, add 25 cc. manganous sulfate-sulfuric acid-phosphoric acid solution and 10 cc. standard ferrous sulfate. Bring to room temperature and titrate excess iron with standard potassium permanganate. Results thus obtained show much better correlation with results of biological study.—*R. E. Thompson.*

Some Color-Producing Organisms in Butter-Washing Water. G. F. V. MORGAN. New Zealand J. Agr., **41**: 315–8, 1930. From Chem. Abst., **25**: 748, February 20, 1931. Following organisms were isolated from butter-washing waters: (1) *Chromobacterium violaceum*, producing violet spots; (2) *Rhodococcus rosaceus*, producing pink coloration; (3) *Bacterium fluorescens*, producing green coloration; and (4) short Gram-positive rod of uncertain classification, forming bright orange pigment.—*R. E. Thompson.*

Application of a Bromine Method in the Determination of Phenol and Cresols. R. D. SCOTT. Ind. Eng. Chem., Anal. Ed., **3**: 67–70, 1931. From Chem. Abst., **25**: 665, February 20, 1931. As result of experimental work described in this paper, following method of analysis was devised and found reasonably accurate. After preliminary purification of sample add sufficient water to an aliquot containing about 0.02 gram of phenol or cresol (in 500-cc. glass-stoppered flask) to make volume exactly 200 cc., and exactly 25 cc. of 25 percent potassium bromide solution. Add 10 cc. 6 normal hydrochloric acid and heat on water bath kept exactly at 25° until contents of flask reach this temperature, then add exactly 25 cc. 0.3 percent potassium bromate solution. Mix well and let stand at 25° for 1 hour, shaking occasionally. Then add 25 cc. 20 percent potassium iodide solution, mix, allow to stand 30 minutes at 25° with occasional shaking, and titrate liberated iodide with standard sodium thio-

sulfate. Run blank determination in same manner. The difference between the 2 titrations multiplied by 0.00157 gives weight of phenol and cresol in terms of phenol.—*R. E. Thompson.*

The Electrochemical Behaviour of Metals. I. The Passivity and Corrosion of Iron. Joseph F. Chittum. J. Phys. Chem., **34**: 2267–85, 1930. Chem. Abst., **25**: 671, February 20, 1931. Acid, hydrogen peroxide, colloidal, chemical, and electrochemical theories of corrosion are reviewed and discrimination is made between general surface, pitting, and "water-line" types of corrosion. In passivity produced by anodic polarization at high current densities, time factor is important. Author's theory explains production of hydrogen in corrosion processes and also consumption of oxygen when iron corrodes in closed vessel. Other characteristics of passive iron, notably absence of oxide layer as shown by optical and X-ray evidence, substantiate present view, obtained by study of electrode reactions in various acid media. In present study sticks of iron subjected to variable heat treatments and mechanical roughening were used in potential measurements. Effects of various anions on the iron negative voltage were studied and conditions defined for acquisition, by the iron electrode, of highest anode and cathode potential densities.—*R. E. Thompson.*

The Mechanism of the Bactericidal Action of Ultra-Violet Rays. Otfrid Ehrismann. Z. Hyg. Infektionskrankh., **111**: 618–43, 1930. From Chem. Abst., **25**: 721, February 20, 1931. Exposure of physiological saline suspensions of bacteria to ultra-violet light causes a clearing, conditioned by passing of cell substance into solution, as recognized by decrease in volume of suspended particles, and by appearance of nitrogen-containing compounds in surrounding fluid. The different bacteria tested can be arranged in series according to their sensitiveness. Accelerated chemical decomposition of bacterial proteins into amino acids under influence of ultra-violet rays cannot be recognized. Increase in temperature, displacement of pH to acid point, and addition of formaldehyde, or of mercuric chloride, inhibit clearing. Following cations inhibit the action in order indicated: lanthanum>calcium> barium>strontium>magnesium> sodium, lithium, potassium.—*R. E. Thompson.*

Biochemistry of Aluminum. I. Kenneth Mackenzie. Biochem. J., **24**: 1433–41, 1930. From Chem. Abst., **25**: 740, February 20, 1931. No harmful effects on general growth and metabolism result from feeding comparatively large amounts of aluminum (to pigs).—*R. E. Thompson.*

The New Elbe Water Supply Plant at Aussig, Czechoslovakia. E. Krob and Th. Gruschka. Gas- u. Wasserfach, **73**: 1057–65, 1930. From Chem. Abst., **25**: 754, February 20, 1931. One of the first Adler high-chlorination and dechlorination plants. Bank-filtered water from wells is obtained from two sources, one giving ordinarily pure water, the other, mixture of ground and surface waters. Ordinarily, latter source alone requires extensive purification. Addition of alum and (or) iron sulfate is followed by chlorination and settling,

after which water is passed through rapid and slow sand filters. After a second chlorination water is passed through Depurit active charcoal filters to remove chlorine, etc. Active charcoal filters are regenerated with sodium carbonate solution at monthly intervals and by occasional steaming. Resultant water is free from taste, odor, and color. Less elaborate purification is employed when possible.—*R. E. Thompson.*

The Water Supply of Stuttgart, Germany, and the Use of Active Charcoal. E. LINK. Gas-. u. Wasserfach, **73**: 985–92, 1016–22, 1033–8, 1930. From Chem. Abst., **25**: 754, February 20, 1931. Principal sources of water supply at Stuttgart are the "Landeswasserversorgung" with source 100 kilometers distant, the Gallenklinge peak-load and emergency source, which takes water from park lakes, and the Neckar water works, together with number of smaller works. The Gallenklinge and Neckar waters require special purification. High chlorination (two stages) is employed to insure sterility and after clarification and filtration an ADLER Mutonator or active carbon filter is used to remove excess chlorine and chlorinated compounds. Chlorinated sodium carbonate solution is employed for regenerating the charcoal and this is followed by treatment with calcium chloride solution to remove alkali and to deposit calcium carbonate. Colorless, odorless, and tasteless water results. Experimental and operating details are included.—*R. E. Thompson.*

Biological Investigation of Stuttgart Park Lakes as Related to Water Supply. R. ENGLER. Gas- u. Wasserfach, **73**: 1081–90, 1930; cf. C. A., **24**: 3845. From Chem. Abst., **25**: 755, February 20, 1931. Seasonal and biological changes in water of Stuttgart park lakes are discussed with respect to causative factors and effect on water supply.—*R. E. Thompson.*

Experiences with Water Supply from Reservoirs on Streams (Talsperren). LEMBERG. Gas- u. Wasserfach, **73**: 1129–36, 1930. From Chem. Abst., **25**: 755, February 20, 1931. Experiences regarding water yield, etc., also graphs showing free carbon dioxide, permanganate requirement, bacterial count, etc., are given.—*R. E. Thompson.*

New Investigations of the Chemical Treatment of Drinking Water. H. KLEPETAR. Gesundheits-Ing., **53**: 641–3, 1930. From Chem. Abst., **25**: 756, February 20, 1931. Study was made of concentration of chloramine needed to sterilize cultures of *B. coli*, etc. Sterilization was complete in very short periods when acetic acid was added to extent of 0.5 cc. per liter. Sodium derivative of *p*-toluenesulfonchloramide was used as disinfecting agent.—*R. E. Thompson.*

Operation of New York's Water Supply System. W. W. BRUSH. Water Works & Sewerage, **78**: 4, 97, April, 1931. New York practice is concisely stated. Marginal strips around each reservoir are all the land purchased for protection since chlorination has been available. Patrol of watersheds is being done with fewer inspectors but these inspectors are equipped with autos when many inspectors before had to walk. Bathing takes place in some

tributaries although it is prevented on city owned land. Boating, fishing and ice cutting are allowed under regulations. Sewerage systems are built by the city, approved by the State Health Department when large enough and house connections paid for by the residents. Some streams are chlorinated when conditions warrant it. This water is chlorinated again later; sometimes twice. The city pays taxes on lands and structures amounting to over $1,000,000 annually. 30 to 40 thousand pine seedlings are planted annually on water supply lands. Copper sulphate is used for organisms. On Croton system the chemical is introduced by pumping on the upstream side of a small dam. Launches or boats are generally used. Vegetation on exposed areas is not destroyed. No detrimental effect on the quality of the water has been observed. Chlorination prevents growths in the aqueducts. Patrol, leaks and construction of other structures across the aqueducts are also discussed. The aerators break up some of the fragile organisms but are not considered essential for satisfactory operation. Chlorination application is 2 to 3 lbs. per million gallons generally. The residual chlorine sought is 0.1 p.p.m. Enclosing the distribution reservoirs with wire link fence has reduced suicides. The distribution mains are purchased, stocked and laid by the Water Department. All mains are sterilized with chlorine and bacterial samples collected whenever possible. An elaborate system is maintained for repair work. Electric drive is replacing steam for pumping. High pressure fire service is furnished during fires.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abst.).*

Settling Basins for Coagulated Water. JOHN R. BAYLIS. Water Works & Sewerage, **78**: 4, 85, April, 1931. Continuous sludge removing devices in water treatment started about 1923. Coagulated water should be settled to the point where it can be handled satisfactorily by the filters. The writer ventures the opinion that it is economy to settle water below turbidity of 20; that under nearly all conditions it will be economy to settle below turbidity of 10, and under average conditions to a turbidity of 5 or less. To reduce the mixing basin velocity to that of the settling basin is difficult. Enlarged sections and baffling are used extensively. It is believed that the best design for the entrance to fairly long basins where the turbidity is high is to direct the water over a baffle in such a manner that the overturning will be in the opposite direction of the way it usually occurs. Entrance velocities of 0.3 to 0.5 ft. per second are best. Cross baffling brings the partially settled water up to the surface so as to prevent overturning.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abst.).*

Survey and Report of River and Stream Conditions in the State of Maine, 1930. A committee of representatives of the paper and pulp mills of Maine organized a survey of five of the principal rivers of the State to determine the present sanitary condition of these streams, with particular attention to the effect of pollution by paper mill wastes. Organization, methods of procedure and findings are clearly presented in the form of tabulated data and graphs, all of which are discussed for each particular stream investigated. Detailed analytical results, river discharge estimates and methods for performing the dissolved oxygen and oxygen demand tests are included in separate appendices.

The general conclusion drawn from the surveys is that with one exception all the river sections examined contained sufficient dissolved oxygen to maintain fish life (3 p.p.m.) and that the oxygen demand of the different pulp and paper mills waste ranges between a fraction of 1 percent and 10 percent of the amount of oxygen available in the stream water.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abst.).*

Shall Illinois Have Sanitation and Conservation of Its Streams? H. F. FERGUSON. Reprint from Illinois Health Quarterly, April 1931. This reprint describes the Sanitary Water Board Law as passed by the legislature in 1929, giving a brief statement of the members composing the board, why certain departments of the State government were selected to be represented on the board, powers granted to the board and the progress in stream sanitation and conservation for the first two years the law has been in force, citing several examples of complaints received by the board.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abst.).*

New Swimming Baths at Bournemouth. Surveyor, **78:** 2009, 101, July 25, 1930. The building occupies a wedge-shaped site with space for future extensions and contains a large club room 25 ft. by 70 ft. and a swimming pool 36 ft. by 75 ft. The engineering plant for the building supplies power for lighting, electric power, heating and ventilation, water filtration and laundry. The water in the pool is recirculated once every four hours. The water from the pool passes through a strainer, is chlorinated, filtered, heated to 75°F., aerated, rechlorinated and returned to the pool.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abst.).*

Bristol South Baths. Surveyor, **79:** 2048, 469, April 24, 1931. With the opening of the present new building, Bristol now has four such modern establishments in addition to a swimming pool used by over 50,000 persons last summer. The new building has a floor space of 23,000 sq. ft. and is modern in every respect. The bath hall, 125 x 59 ft. contains the swimming pool 100 x 35 ft. and capacity of 130,000 gallons. The water is continuously filtered, warmed, aerated and disinfected. The architectural features, details of bathing features and accessories are described. The entrance hall 46 x 22 ft. not only provides access to every department, but during winter months will act as a crush hall when the bath is floored over and used for various public functions.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abst.).*

Public Indoor Swimming Pools of Connecticut. J. HENRY L. GILES. Connecticut Health Bulletin, **45:** 3, 75, March, 1931. This is a report of the results of a recent inspection of public indoor swimming pools in Connecticut. Methods of disinfection, bacterial quality of the water, residual chlorine, hydrogen ion concentration, alkalinity control, and results obtained are briefly described.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abst.).*

Round Chart Micromax Indicating Recorder. Leeds & Northrup Company, Philadelphia, Pa. A new round-chart Micromax Indicating Recorder and a

new multi-purpose case for the Micromax Recorder are announced by the Leeds & Northrup Company. There are four of the single-point Micromax instruments, one for recording CO_2 in the combustion range, one recording pressure over a range of 0–200 lb. per sq. in., one recording room temperatures and one recording temperatures in the range of 400–900°F. It has a boldly-lettered circular scale that can be read at a glance across a large room and uses a 24-hour circular chart that has straight-line time coördinates instead of curved ones. The new case is dust-tight, and vapor-tight when desired and can be supplied for mounting in any position specified.—*A. W. Blohm.*

The Nashville, Tennessee, Filtration Plant and Water Proofing of Large Reservoir. JOHN F. LABOON. Proc. 36th Convention of American Society of Municipal Engineers, 367. The author gives a description of the 51 m.g. Kirkpatrick Hill reservoir and the method of waterproofing the reservoir at a cost of over $202,000. In addition a new 28 m.g.d. gravity filtration plant was started in 1927 and dedicated in 1929. A brief description of the new plant with other improvements to the water system is given.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abst.).*

Modern Methods of Feed Water Treatment. J. JELINEK. Gas- und Wasserfach, **75:** 13, 250, March 26, 1932. Trisodium phosphate is advocated because therewith (1) silicic acid forms sodium silicate, (2) clarification is obtained, (3) no volatile constituents are added, (4) no corrosive action has been observed, and (5) control is simple, since slight excess is not harmful.—*W. G. Carey.*

New Water Works for the City of Hamm, Germany. Gas- und Wasserfach, **75:** 12, 231, March 19, 1932. City authorities have agreed with electricity works that latter shall sink wells and supply town with water for next thirty years at fixed price. Advantages of association between water and electricity works are discussed.—*W. G. Carey.*

Examination of the Development of Central Water Supplies in Germany since 1911. K. HÜNERBERG. Gas- und Wasserfach, **75:** 17, 310–317, April 23, 1932 and 18, 336–339, April 30, 1932. Particulars of 76 water undertakings, given to illustrate development since 1911, comprise water demand, charges, income, expenses, and profits. Since demand in near future is unlikely to reach peak of 1929 and 1930, large extensions of supplies or of treatment plants are not anticipated, but reserve funds should be built up and endeavours made to keep price of water low. Towns are tabulated as to population and per capita consumption and some eighteen diagrams and charts given.—*W. G. Carey.*

Corrosion Problems. I. General. THIESING. Gas- und Wasserfach, **75:** 14, 253–255, April 2, 1932. Water section of Deutscher Verein von Gas- und Wasserfachmännern has formed committee to publish practical experience of corrosion. Survey is given of present knowledge of corrosion of water pipes by water, air, and soil; acid and electro-chemical theories are discussed, as well as action of carbon dioxide, oxygen, and salts, formation of protective layers, and effects of composition and construction of metal.—*W. G. Carey.*

Corrosion Problems. II. Iron. E. NAUMANN. Gas- und Wasserfach, **75**: 19, 349–351, May 7, 1932. Corrosion proceeds in practically all waters; carbon dioxide commonest cause, forming iron oxide and calcium carbonate; but oxygen also responsible and is chief corrosion factor in hot water. High calcium carbonate content forms scale, limiting action. External corrosion of mains is associated with water and is produced by condensation; zinc coating is of little value; bitumen is more resistant than tar. Cast iron pipe is stated to be preferable to steel from corrosion standpoint, but there is more risk of breakage through subsidence. Corrosive waters are aërated, or treated with lime. Corrosion of hot water pipes is lessened by having open end at highest point. Reference is made to removal of oxygen with sodium sulphite solution.—*W. G. Carey.*

Corrosion Problems. III. Aluminum, Lead, Copper. L. W. HAASE. Gas- und Wasserfach, **75**: 20, 372–374, May 14, 1932. Protective coating of aluminum oxide and lime is formed in aluminum cooking utensils, but is destroyed by solutions of sodium chloride, or of soda, or by iron, or copper, in water used. Protection is afforded by artificial oxide layer, or by plating with pure aluminum. Lead is attacked by cold water having acid reaction, notably that containing free carbon dioxide. Protective coatings are formed only in waters containing oxygen and much carbonate, and are destroyed by hydrogen sulphide, humates, chlorides, nitrates, nitrites, or sulphates. Lead pipes should be used only for cold water and then only when no continuous solution of lead will take place. Copper resists attack by cold or hot water, or by water containing salts, the amount which may go into solution being negligible.—*W. G. Carey.*

The Water Works of the City of Halle, Germany. K. SCHMIDT. Gas- und Wasserfach, **75**: 11, 193–201, March 12, 1932. Supply is drawn from 360 wells sunk in gravel between two rivers. Infiltration is augmented by brook connecting rivers, which has been converted to seepage channel with ponds for settlement of river water before infiltration. Water obtained is sterile, but 0.2 p.p.m. chlorine is normally applied and in times of flood, an excess dosage, employing sulphur dioxide, or activated carbon, for dechlorination. Iron (1.2 p.p.m.) and manganese (0.5 p.p.m.) are removed by aëration followed by rapid and slow filtration. Pumping plant and distribution system are described, with 16 illustrations.—*W. G. Carey.*

Submerged Pumps at Frankfurt a. M., Germany, Waterworks. G. VIESOHN. Gas- und Wasserfach, **75**: 9, 158–164, February 27, 1932. Frankfurt has recently installed in wells at depth of 59 feet below original ground water level four centrifugal pumps working against total head of 230 feet which dispense with water lubrication and are readily accessible. In two pumps, positive air pressure from compressors on surface keeps inside of motor casing free from water, compressors automatically coming into operation at 3 atmospheres and cutting off at 4.2 atmospheres. Large air chests prevent infiltration of water when pumps idle. In other two pumps, water is blown out at intervals by compressed air from sump in motor casing, which when filled operates float contacts switching on and off compressors at surface. Provi-

sion is made to prevent pumps running dry. Pump efficiencies range between 57 and 65 percent, which is so satisfactory under such circumstances that similar pumps are being installed at Hattersheim.—*W. G. Carey.*

Solubility of Calcium and Magnesium Carbonates in Carbon-Dioxide-Free Water. J. LEICK. Zeitschrift für analytische Chemie, **87**: 415, 1932. Solubility of calcium carbonate in water free from carbon dioxide depends on amount of solid phase and varies between 12.5 and 14.5 p.p.m. at 100°C. It decreases with increasing temperature and alkalinity and is increased by presence of sodium chloride, or sulfate. Solubility of magnesium carbonate is independent of amount of solid phase, and is 27 p.p.m. at 100°C., two-thirds being carbonate and one-third bicarbonate. Solubility increases with decreasing temperature; boiling solution decomposes to hydroxide and carbon dioxide, neutral salts and alkalinity accelerating this.—*W. G. Carey.*

The Surbiton Waterworks of London, England. ANON. The Engineer, **154**: 4007, 428–429, October 28, 1932 and 4008, 452–455, November 4, 1932. Pumping plant, dealing with water taken from Thames at Walton, has recently been remodeled. Capacity of 28 slow sand filters is 45 m.g.d.; but pumping plant can handle 60 m.g.d. Four 10-stage turbines taking steam at 250 pounds pressure and running at from 5700 to 6300 r.p.m. drive, through gearing, centrifugal main pumps and booster pumps; they are arranged to trip for overspeed, for failure of vacuum, or for excesive pump-suction head. Condensing plant consists of four cylindrical 3-phase surface condensers with steam air-ejectors to maintain 28 inches vacuum. Main pumps are of double-suction, single impeller, volute type. Boiler-house contains three 4-drum boilers, with superheaters, chain-grate stokers, economisers, air preheater, etc. Coal is conveyed from barges by endless belt and gravity bucket 25-ton-per-hour conveyors. Filtered water, softened by zeolite and de-aërated, is used for boiler feed. Considerable economies are expected; average fuel consumption of old plant was 3.7 pounds per water horse power per hour, whereas new contract calls for 2.0 pounds, and probably, under normal conditions, 1.7 pounds will not be exceeded; estimated saving being £4000 per annum.—*W. G. Carey.*

Boiler Sludge, a Hitherto Unrecognized Source of Danger. H. RICHTER. Chemiker-Zeitung, **56**: 173–174, 1932. From Chemistry and Industry, **51**: 24, **B**483, June 10, 1932. Feed water, whether softened by zeolite, sodium carbonate, or sodium phosphate, has small residual hardness resulting in sludge. Sodium carbonate and bicarbonate hydrolyze and resulting carbon dioxide coats particles of sludge which settle around seams, rivets, ends, and tubes. Local high concentration of carbon dioxide has corrosive action on iron, forming iron carbonate and ultimately oxide which increases sludge and accelerates corrosion. Caustic soda produced causes embrittlement, and portions of boiler to which sludge adhere act anodically to relatively clean portions. Remedy appears to be more frequent removal of sludge, e.g. by opening sludge cock every one to two hours.—*W. G. Carey.*

Irony Water. A. R. RAWLENCE. Official Circular of British Waterworks Association, **14**: 98, 50, February 1932. Action of water on iron pipes may be

prevented by using pipes not attacked by the micro-organisms, by aëration, or by sterilization with lime. The first is generally too expensive; the second, cheap, if sufficient head for cascade or fountain is available; and the last is often advantageous, as besides killing organisms lime improves taste of soft water.—*W. G. Carey.*

On the Precipitation of Calcium Carbonate from Dilute Solutions. F. CORIN. Annales Soc. Géol. Belgique, 53: 64–66, January 19, 1930. Four forms of calcium carbonate may apparently exist in equilibrium with dilute solutions. Calcite is stable: aragonite occurs only infrequently, and is rapidly transformed into calcite. In powder form, these different minerals are difficult to identify.—*R. DeL. French.*

Hydraulics in Roman Tunis. G. PIGNAUVIN. October 2, 1932, (reprint). Romans collected underground water on hilly slopes by means of trenches 1 meter deep. Trench bottoms were coated with clay, and trenches were filled with fascines of pine, on which large stones were placed. Flanking dams, to direct water to these trenches, were built by grouting permeable soils with clay.—*R. DeL. French.*

Determination of Total Dissolved Solids in Water Analysis. C. S. HOWARD. Ind. Eng. Chem., Anal. Ed., 5: 1, 4, January 15, 1933. Total solids determined by evaporation and heating for 1 hour at 180°C. is reasonably close to sum of determined constituents for most waters. Carbonate waters high in magnesium may give low residues; sulfate waters usually give high residues. Residues from high chloride waters may lose on heating from 50 to 100 p.p.m. and those from high nitrate waters, 30 p.p.m. Waters of high solids give more consistent results when small volume only is evaporated in weighing bottle.—*Edw. S. Hopkins.*

Ammonia-Chlorine and Activated Carbon Treatments of Water. A. PRESCOTT FOLWELL. Public Works, 63: 5, 18–21, May 1932. Ammonia-chlorine treatment saves chlorine, prevents tastes due to phenols, or to excess chlorine, and provides stable and efficient disinfection, even in presence of considerable organic matter, for long periods. Water treated with chloramine must be retained at plant until sterilization completed, action proceeding much more slowly than with chlorine. In testing chloramine-treated waters for residual chlorine with *ortho*-tolidine, thirty minutes must be allowed for development of color. Ammonia and chlorine should be applied to water successively in order given, with only a few minutes between. In general, ammonia dosage one-third of that of chlorine is satisfactory, but optimum ratio should be determined by trial. Ammonia may be introduced as gas, or as ammonium salt: data are insufficient to indicate any preference either way. Costs usually exhibit substantial saving, due to decreased consumption of chlorine. Activated carbon is useful in removing tastes and odors due to algae, to swampy and vegetable matters, to phenols, to hydrogen sulfide, to chlorine, or to other soluble matters. Sludge accumulating in settling basins and in water softening units is therewith rendered inodorous. Experience indicates mixing chamber of secondary coagulating basin as best point of application.

One softening plant adds activated carbon to alum solution, which is fed to water entering down-take in softener. This produces a balanced water without recourse to recarbonation. Most common method of application is by dry-feed machine and water ejector. Average dosage for ordinary conditions is 2 p.p.m.; for severe conditions, 10 p.p.m. may be needed. Moderate dosages will cause little or no clogging of filters. Costs for 2 p.p.m. application approximate 84 cents per million gallons; while 10 p.p.m. may cost $4.17. Method has been devised for testing absorptive capacities of carbons.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

Increasing Efficiency of Water Purification at Valparaiso, Indiana. CHAS. BROSSMAN. Public Works, **63**: 5, 15–17, May 1932. Plant was modernized by installation of new filter bottoms, control mechanism, Aer-O-Mix header tank, and dry-feed machines. Filter troubles have disappeared, settling basin efficiency has been increased and saving of wash water and of alum has been effected.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

Water Works Improvements at Murfreesboro, Tenn. C. N. HARRUB. Public Works, **63**: 3, 24–6, March 1932. Gravity type filtration plant was constructed; old boilers were replaced; new power plant and half-million-gallon elevated steel storage tank were erected; and belt line of 8-inch and 12-inch pipe was added to improve distribution pressure. Filtration plant includes two 125,000-gallon sedimentation tanks, four half-million-gallon rapid filters, and million-gallon filtered water reservoir. Prior to construction, site was core drilled. Mud pockets rendered solid rock foundation impracticable, so columns and girders were used to support entire structure.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

Water Softening Plant for Marshall, Missouri. BRANSFORD W. CRENSHAW. Public Works, **63**: 5, 38–40, May 1932. Consumption averages 381,000 g.p.d. Two units of zeolite type have been installed, with space provided for a third, receiving water direct from wells. Pulsations from well pumps are absorbed in cushion tank. Automatic proportioning of treated to untreated water permits variation of from one to eight grains per gallon in final hardness. Approximately 55,000 pounds of rock salt will be used per month. This supply is placed in concrete tank, from which concentrated brine flows to underground tank where it is properly diluted before being pumped to softeners. Zeolite employed has softening capacity of 4,500 grains of hardness per cubic foot. Salt consumption is 0.35 pounds per thousand grains of hardness removed. Cost for entire project approximates $30,000.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

The Influence of Metallic Radiations on the Vitality of Micro-Organisms. HUMBERT BOUCHER. Jour. de Pharm. et de Chem., **16**: 556, December 16, 1932. In experiments under review, metallic radiations had no attenuating effect upon vitality of micro-organisms: on the contrary, they seemed to prolong the lives of *B. coli* and staphylococci.—*R. DeL. French.*

On the Determination of Hydrogen Sulphide in Industrial Waters. M. KNAPP. Jour. de Pharm. et de Chem., **16**: 90, January 16, 1933. To prevent oxidation of hydrogen sulfide during transport, excess of cadmium sulfate solution is added to sample in field. Resultant precipitate of cadmium sulfide resists oxidation. On reception at laboratory, sample is decanted into flask and distilled after addition of dilute sulphuric acid. Hydrogen sulfide liberated is absorbed in known excess of iodine and excess titrated with sodium thiosulfate.—*R. DeL. French.*

Baltimore Doubling Her Water Storage. R. G. SKERRETT. Compressed Air Magazine, **37**: 10, 3948–51, October, 1932. Prettyboy Dam, under construction on Gunpowder River, 25 miles north of city, will, when completed, add very substantially to city's reserve during months of light rainfall. It will form basin upstream for 7¼ miles capable of holding 20 billion gals. from drainage area of approximately 50 square miles. While site of basin was desirable and elevation favorable, suitability for foundation purposes of outcropping rock (mica schist), which had tendency to overbreak when blasted, was in some doubt at first. Special drills and wire saws were, however, used on rock very satisfactorily. Work was started November 17, 1930, and is expected to be completed by end of 1932. Total height of structure is 188½ feet; maximum base width of highest part, 122 feet; bridge width on top of dam, 31 feet, 10 inches; length 692½ feet; length of spillway beneath bridge, 274 feet. Total length of structure is 855 feet. Ultimate cost is expected to reach $3,500,000.—*R. H. Oppermann.*

Solution of Special Problems in Pipe Flow by Graphical Analysis. GRANT K. PALSGROVE. Rensselaer Polytechnic Institute Bulletin **37**: 29 pages. August, 1932. This bulletin describes how the application of graphical analysis leads directly to a definite result. Typical fundamental problem analyses are made on "long pipes," i.e. those of length not less than 1,000 diameters, including compound pipes in series, compound pipes in parallel (looping), three branching mains (dual flow), economic sizes in branching pipe system (dual flow), and four branching mains, one of which is compounded in series (dual flow).—*R. H. Oppermann.*

Turbulence in Centrifugal Pumps. J. W. MACMEEKEN. Hydraulics: Trans. A. S. M. E., **54**: 15, 47–63, August 15, 1932. Flow of rivers in curves may be calculated on same basis as flow in straight canals by using correction factors which are function of the curvature and, similarly, flow of water in centrifugal pump and its effect on generated head may be calculated by the use as correction factors of similar functions of channel curvature. Paper further discusses method of obtaining synchronization of effect of vortex action in mixed flow impellers, where flow may be regarded as series of parallel spiral forced vortices in impeller, modified to some extent by included local free vortex action.—*R. H. Oppermann.*

Leakage Loss and Axial Thrust in Centrifugal Pumps. ALEXEY J. STEPANOFF. Hydraulics: Trans. A. S. M. E., **54**: 15, 65–111, August 15, 1932.

Deals with experiments at University of California at four different speeds and under different heads. As new sources of thrust were established unequal inside pressures on impeller shrouds due to various causes, most important of which are uneven radial velocity distribution and cavitation. In multi-stage pumps with impellers mounted back to back, generally considered balanced, it was discovered that there is axial thrust produced by unequal pressures in adjacent stages acting upon the shaft shoulders and impeller hubs extending through intervening walls. Means to eliminate this were found. In pump with volute case, when working below normal capacity, maximum pressure is at discharge flange; when working above normal, pressure in volute case exceeds that at discharge flange. Volute pressure at point of maximum efficiency can be determined with sufficient accuracy from pump discharge pressure by assuming the nozzle efficiency. For pump tested, nozzle efficiency was found to be 60 percent.—*R. H. Oppermann.*

The Shannon River, Ireland, Power Development. Civil Engineering (Eng.), pp. 18–24, August 1932. Describes experiments with models. (1) To determine nature of discharge through weirs, to assist in design of Shannon Dam. (2) To aid in design of overflow, or waste, channel at power station intake. (3) With models on scale of 1 to 50, to determine effect of conditions in sluice. (4) To study discharge phenomena at different tail-water levels, so as to show advantages of stilling basins. (5) To investigate different control methods for filling and opening of locks. Relations between time factors on models and on plant as constructed were found in complete agreement. Value of models in design of large works was conclusively demonstrated.—*E. B. Besselievre.*

Construction of Menden Service Reservoir, Coventry, England. A. C. Jack. Civil Engineering (Eng.) pp. 12–17, August 1932. Wells were sole dependence of Coventry until 1907, when supplementary supply was obtained from Birmingham. Coventry Water Act, 1928, authorized construction of 3 reservoirs; Menden of 10 mg. (Imp.) capacity; Coundon, of 9. m.g.; and New Corley, of 0.8 m.g.; and of one water tower, of 0.3 m.g.; augmenting total storage to 24.0 m.g. Imp., or 4 days supply, and displacing boosters. Menden reservoir, situated on main road to Birmingham at elev. 500 feet above datum, is of circular plan, 280 feet in diameter and 25 feet 6 inches deep. Inlet and outlet are arranged in one chamber; circulation is by means of enclosed flumes, with collection and delivery at opposite ends of one diameter. Overflow chamber is at circumference, convenient to drain. Design is monolithic. Details are given of construction and of handling of materials. Barrel arch roof, of which details shown, rests on 116 columns arranged in concentric circles. Formula for concrete mixture outlined by Prof. Abrams was adopted. Total volume of concrete was 8890 cubic yards. Tests on concrete described. Total cost was $129,000, reckoning pound sterling at $3.80.—*E. B. Besselievre.*

The Serological Classification of Lactose Fermenters (*B. Coli*) as a Guide in Determining Their Source. T. Sitapati Ayyar. Indian J. Med. Research, 20: 489–504, October, 1932. Specific agglutinating sera were prepared from

lactose fermenting organisms isolated from dysenteric stools and from calf-dung, respectively. Homologous types of organisms were found in high ratios in normal specimens of intestinal excreta of men and cattle when tested against sera so prepared. A very large percentage of lactose fermenters isolated from soils were not clumped by either serum (soil type). It was found that human type predominates about 3.5 times over bovine in human feces; bovine type about 13.5 times over human in cattle dung; and soil type about 33 times over those of animal origin in soils. Similar tests on sewage showed 37.5 percent of lactose fermenters to be of animal origin, of which 91.5 percent were of human type. Lactose fermenters in excreta of small animals and birds (rabbits, monkeys, and pigeons) were found to be chiefly (95–98 percent) of soil type. Serological method compares very favorably with chemical and bacteriological methods of judging suitability of water for domestic use. In an experiment to determine whether contamination was transmitted from a pit in which fecal matter had been deposited to boreholes located radially 20 feet therefrom, serological method demonstrated presence of lactose fermenters of human type within a week; while bacteriological and chemical methods failed to demonstrate definitely presence of fecal contamination during course of experiment, which extended over 7 months. It should be pointed out, however, that only those samples which contained lactose fermenters in 0.1 cc. amounts, or less, were considered definitely contaminated: samples containing lactose fermenters in 1 cc. were classified as suspicious and those containing these organisms in 5 cc. quantities and upwards, as potable.—*R. E. Thompson.*

Pollution of Water Supplies. LEO T. PARKER. Municipal Sanitation, 3: 11, 458, November 1932. Measure of damages for pollution of privately owned stream is difference in private property value of same, as before and as after pollution, or, what it would reasonably have cost to furnish, or procure, including time and trouble, adequate supply of water. Different rule applies to pollution of water used by municipality. Courts held that damages allowable to municipality for pollution of water are dependent upon cost of acquiring and installing adequate means for supplying pure water. In Roxana Corporation *vs.* City of Pawnee, 7 P. (2d) 663, company polluted source from which municipality obtained its supply. Proper measure of damages is cost of acquiring and installing another adequate and enduring supply of water identical with that used prior to pollution, including also necessary expense incurred for reasonable time in providing and maintaining temporary supply, pending acquisition of permanent supply. **Sanitation Held Governmental Function.** City exercising such power is not liable for injuries inflicted through negligence of its officers and employees. In City of Wichita Falls *vs.* Robinson, 46 S. W. (2d) 965, municipal employee, injured while using disinfectant in discharge of his duties in sanitary department, sued municipality for damages. Court held city not liable. **City Liable for Illness of Citizens.** Oklahoma City *vs.* West, 7 P. (2d) 888. Municipality discharged impure materials into stream, resulting in pollution. Citizens drank the water and became sick. Suit was filed. It was shown that efficient disposal plant could have eliminated such impurities. Higher Court held city liable. **Owner of Damaged Property**

Need Not Prove Negligence. Hunze *vs.* City of Cape Girardeau, 43 S. S. (2d) 882. City had acquired right to use a certain stream at times when principal sewer main was inadequate to carry off all storm water and sewage from sewer system. Principal main became clogged and all sewage was diverted into stream over period of six or eight months, resulting in pollution. Owner of property through which stream flowed filed suit. Higher Court held city liable.—*R. E. Noble.*

When Stream Pollution Is Legal. Leo T. Parker. Municipal Sanitation, 4: 3, 92, March, 1933. Courts speak of both right of navigation and right of fishery as natural rights. Some Courts overlook the fundamental differences, without accounting for origin or existence of the trust, other than that fishery is a "natural right," and have held that state holds its tidal waters in trust for use both for navigation and fishery. On the other hand, right to use tidal waters and bottoms for fishery purposes is no more an incident of necessity than right to take game in the forest, or use unappropriated uplands for pasturage. In exercising it, individual puts tidal waters and bottoms to public use only in same sense that exercising right of fowling upon tidal waters puts them to public use. Public fishery rights are at all times subject to legislative disposal, which may revoke rights at its pleasure by granting individuals exclusive rights, or by dealing with the waters in such way that fishery is destroyed. In Commonwealth *vs.* City of Newport News. 164 S. E. 689, state law authorized city to issue bonds for making improvements in sewage disposal system. Act in part reads: "The proceeds shall be used for the construction of a sanitary sewer to Hampton Roads, for the prevention of pollution in Salters creek and adjoining territory, and the erection of a sewage disposal plant for the protection of said creek and territory." Hampton Roads and James River are suitable for propagating shellfish; planting ground is leased by commonwealth to private persons for considerable annual revenue; fish are also taken in commercial quantities in these waters. Raw sewage discharged by Newport News polluted Hampton Roads and James River in vicinity of city. Health authorities declared waters unfit for propagation of shellfish and for bathing. Fishing was destroyed. With loss of tongers and planters of oysters came consequent loss of large revenue to state. Cases of infectious diseases are directly traceable to eating shellfish from these waters and offensive odors injurious to health of people in vicinity are given off. City has created and maintains general public nuisance, and suit was filed to enforce abatement. Higher Court held that city had legal right to discharge untreated sewage into Hampton Roads and should either (1) construct sewer line that will discharge into Roads proper, or (2) erect sewage treatment plant.

Polluted Water Purified. Owner of private property may recover damages from either city or private corporation which empties impure or poisonous substances into stream which flows over his land. If, however, substances emptied into stream purify, instead of polluting, the water, property owner is not entitled to damages. In Brooks *vs.* Champlin Refining Company, 15 P. (2d) 62, city discharged sewage into running stream, polluting same. Refining company also emptied refuse therein. Property owner filed suit, stating that all substances emptied into stream contaminated the water. Refining

company counsel argued that their refuse aided purification and court held refining company not liable. **City Entitled to Enjoin Use of Lake.** Village of Monroe *vs.* Benjamin, 181 N. E. 581. Municipality leased a lake and utilized its water for domestic purposes. City filed suit to restrain persons from using lake water for any act or acts (bathing, boating, fishing, etc.) likely to pollute the water. Court held that city being the lessee, rules might be made and enforced regulating use of lake by others. **Ice Company Entitled to Recover Damages.** Southern New England Ice Co. *vs.* West Hartford, 159 Atl. 470. Municipal sewer system overflowed and discharged sewage into stream utilized by private ice manufacturing corporation. Higher Court held ice company entitled to $80,000 damages. **Property Owner Delays Suit.** Ordinarily, owner of private property is bound to complain, or file suit, within a reasonable period, in respect of acts of municipal officials which effect injury to his property. However, this is not applicable with respect to water pollution suits. In ANDERSON *vs.* Town of Waynesville, 164 S. E. 583, property owner in 1913 constructed lake for use as health resort. In 1914, town discharged sewage into creek above lake. In 1931 property owner filed suit against town to prevent further discharge. Court held that property owner has not lost his right to insist upon abatement of alleged nuisance. **New Property Owners Obtain Injunction.** Fact that, for many years previously, property owners have, without objection, permitted open sewers, or other forms of water pollution, does not preclude new purchasers of property from obtaining injunction against further pollution. In Town of Lumber City *vs.* Phillips, 164 S. E. 681, several persons who had recently purchased property filed suit against municipality to prevent maintenance of open sewer running through their property, causing pollution. Counsel for city argued that sewer had been there many years prior to purchase of property by new owners. Higher Courts rendered verdicts in favor of latter.—*R. E. Noble.*

Methods of Reducing the Flow of Artesian Wells. HOWARD E. SIMPSON. Bulletin 3, North Dakota Geological Survey, 1924; revised 1932. 7 pp. Methods in use in Dakota artesian area include globe valves for adjustable throttling, gate valves for complete shut-off, ordinary reducing pipe fittings and drilled plugs for fixed throttling, and a specially designed inside reducer recommended for general use.—*R. L. McNamee.*

The Ground Waters of North Dakota. HOWARD E. SIMPSON. Bulletin 7, North Dakota Geological Survey, 1932. 26 pp. This appraisal of ground waters of state opens with discussion of general nature and classifications of ground waters of topographic, climatic, and geological conditions in state as they affect these waters and of natural division of state into three ground water provinces, consistent with its physiography, namely, the Red Run Valley, the Drift Prairie, and the Missouri Plateau. In Red Run Valley, water is obtained from shallow wells in beach and delta deposits and in lake silts and from tubular and artesian wells in the drift and sedimentary bed rock beneath. In Drift Prairie, water is obtained from valley alluvium, from glacial drift and from underlying bed rock: shallow, tubular and deep artesian wells are all common. In Missouri Plateau, in area east of river,

water is obtained from glacial drift and from sandstone and lignites of underlying bed rock; west of river, scanty supplies are found in residual soils covering the driftless area and more abundant supplies in sandstones and lignites of bed rock formations. In Missouri valley proper, valley alluvium is also drawn upon. Much detailed information is recorded concerning characteristics of the several geologic formations from which water is drawn and of the waters themselves. Included in bulletin is fourth biennial report of State Water Geologist upon work of his office.—*R. L. McNamee.*

Gearing for Pump Drives. F. JOHNSON-TAYLOR. Water Works Eng., 85: 20, 1208. October 5, 1932. Internal combustion engine is most efficient prime mover for pumping duties: speed must, however, be geared up for centrifugal, and geared down for reciprocating pumps. Gearing is more efficient and compact than belting; but for satisfactory working, wear must be reduced to minimum by wide teeth accurately designed to secure rolling rather than sliding contact. Case-hardening and grinding are further helps. Tightness, strength, and accuracy are essential. Reduction gearing generally forms integral part of reciprocating pump. Centrifugal and turbine pumps generally have gear assembly separate. Double helical gearing is self-contained and compact and is smoother running than spur gears: area of contact is distributed over several teeth, while in spur gearing one tooth generally takes entire load. Continental European practice leans to spur gears, while Britain uses double helical gearing almost exclusively for heavy loads.—*Lewis V. Carpenter.*

Governmental Duties of the City. LEO T. PARKER. Water Works Eng., 85: 20, 1213, October 5, 1932. Municipality is not liable for negligence of its water works officials or employees who effect damages to persons or property, providing such water works system is operated for comfort and benefit of public and without profit. Governmental functions of city are part of state's sovereignty, delegated to city to be exercised for benefit of the whole public, whether resident in city, or otherwise. In respect of all other functions, which are municipal or ministerial, city is liable for all damage. If city creates nuisance by acts done exclusively in interest of the public, such as improvement of sanitary conditions, it would be liable only for carelessness or negligence. Municipality is never liable in damages for injury sustained as result of negligence by city official or employee acting outside scope of his employment. Negligence is lack of ordinary care on part of municipal officials, which may result in liability for injuries to employees or citizens. Employee engaged in performance of services for his employer is entitled to recover compensation for injuries, particularly if he is within scope of state Workmen's Compensation Laws. Municipality, or private water company, is not liable under state compensation laws for payment of compensation to any person not an employee. Municipality is not liable in damages for injury sustained by another's employee.—*Lewis V. Carpenter.*

Ferric Chloride as a Coagulant. PAUL STEGEMAN. Water Works Eng., 85: 22, 1318, November 2, 1932. Tittabawassee River was chosen as supply for 2-m.g.d. rapid sand filter plant at Midland, Mich. Raw water alkalinity

varies from 100 to 200 p.p.m.; hardness, from 115 to 225 p.p.m.; turbidity, from 10 to 300 p.p.m.; and color, from 35 to 70. Water is treated with 7.5 grains per gallon of hydrated lime, plus coagulant, and is given retention of 35 minutes in basins and of 60 minutes in Dorr Clarifier. Ferric chloride became comparable with alum in cost and was found in series of comparative laboratory experiments with varying doses to give in all cases better turbidity removal with lower dosage. Color removal was found to be due rather to hardness precipitate than to coagulant. After plant scale test proved equally favorable to ferric chloride, saving therewith being appreciable, this treatment was adopted permanently. Doses of about 7.5 grains per gallon of hydrated lime and of 0.25 grains of ferric chloride proved satisfactory. Data on filter runs are not yet available.—*Lewis V. Carpenter.*

The Use of Copper Tubes for Conveying Drinking Water from a Hygienic Aspect. A. MEYER. Monats-Bulletin des Schweiz. Vereins von Gas- und Wasserfachmännern, 12: 7, 220–21, July 1932. Incrustation on copper mains does not consist of verdigris, but of harmless copper and calcium carbonates, and forms protective coating which prevents further solution of metal. Samples of cold and hot water taken at different points from new domestic installation consisting entirely of copper contained, according to chemical and spectroscopic analysis, less than 1 p.p.m. of copper. Samples taken at later date proved to contain still less copper, on account of the protective coating which had formed.—*Manz.*

Boiler Water Conditioning under Primitive Conditions. HUGO HERMANN. Schlägel und Eisen, 30: 3, 56–58, March 1932. Shows how modern feed water conditioning with all its advantages may be applied even in small boiler plants, locomobiles, dredgers, small locomotives, etc., provided tank is available in which to treat feed water with scale solvent, or, better, with soda. Adequate blowing-off is very important and can only be done during service intervals without seriously affecting the rating. Amount of blow-off necessary is shown to depend upon hardness of feed water, density of boiler water, and sulfate concentration: to prevent corrosion, excess of soda is necessary. Feed water must be controlled both as to alkalinity and as to hardness. Before putting out of service, boiler is repeatedly to be alternately filled and then blown down to lowest water level. After last feeding, steam must be strongly blown off to get rid of oxygen introduced with cold water.—*Manz.*

Two Gravity Water Supplies at Opposite Ends of a City, H. G. OLMSTED. The American City, 47: 5, 61–62, November 1932. Alpine, Texas, has two gravity flowing reservoirs, one on each side of city, with source of supply adjacent to each. New development includes four wells on mountain side, south of city with suitable deep well turbine pumps and reservoir, and 500-foot well with deep well turbine pump on hills east of city. Water is disinfected with chlorine.—*Arthur P. Miller.*

Water Supply and Sewage Disposal for an Indiana State Institution. CHAS. BROSSMAN. The American City, 47: 5, 69–71, November 1932. New water

supply for Muscatatuck Colony in Indiana includes intake in Muscatatuck River, aërating devices for odor removal, settling, and modern filtration. Spray nozzles are used for aëration. Alum, is fed dry and, after 20 minutes' mixing, treated water passes into 6-hour-retention coagulating basin. Chlorination follows.—*Arthur P. Miller.*

Cucumber Taste Removed. C. J. BRUCE. The American City, **47**: 5, 75, November 1932. New dam on Cumberland, Maryland, water supply increased length of natural settling basin above dam by three miles. Asterionella developed in large quantities and produced objectionable taste. Activated carbon was promptly procured and fed to filters at rate of 0.3 grain per gallon. Taste was eliminated at filter plant in one day and completely disappeared from all city mains a few days later.—*Arthur P. Miller.*

The Use of Activated Carbon in Water Purification. C. MÜLLER. Wasser u. Gas, **23**: 9 & 10, 545–52, 1933. Molded (pellet-form) activated carbon is preferable to unmolded granular carbon in its greater adsorption capacity, density, durability, and hardness, and in its smaller fatigue factor, lower loss of head, and permitting reduction in filter size. Pellets cannot compete in price with unmolded carbon, one recently introduced brand of which rivals pellets in adsorption capacity. Original adsorption capacity of a given carbon varies inversely as particle size, but fatigue factor is independent of it. Granular carbon can be used in pressure filters with upward or downward flow or in open filters. Use of powdered activated carbon is more widespread at present in America than in Germany. It can be either (*a*) applied directly to water, or (*b*) in form of a suspension raked into top 10 or 15 cm. of slow or rapid sand filter. Since in (*b*) water is practically purified before reaching carbon, adsorption capacity of latter is more fully utilized, and therefore carbon consumption is less and filter runs are longer. Powdered carbon is more easily applied than granular and better suited for intermittent use.—*Selma Gottlieb.*

"Verdunization," the Procedure of Bunau-Varilla for the Chlorination of Drinking Water. Description and Investigation. MUHIDDIN ALI. Tech. Gemeindeblatt, **35**: 22, 269–73, 1932. The work and claims of BUNAU-VARILLA, his adherents and critics are discussed. Even with vigorous shaking, effectiveness of sterilization by 0.1 p.p.m. chlorine is not independent of chlorine demand of water. Shaking increases bactericidal effectiveness only by more rapid mixing, and benefit was not always significant. Waters with slow rate of chlorine absorption are more easy than others to disinfect, less chlorine sometimes sufficing for disinfection than indicated chlorine demand. Water previously sterilized was used in most cases. Such sterilization considerably reduced the chlorine demand.—*Selma Gottlieb.*

The Colorimetric and Gravimetric Procedures for the Determination of Arsenic, Especially in Water and (Filter) Mud. H. SCHRÖDER and W. LÜHR. Z. Untersuch. Lebensm., **65**: 2, 168–76, 1933. [See also BARTOW and BENNETT, THIS JOURNAL, **2**: 4, 585–95, December 1915.—ABSTR.]. For determination of

arsenic in water, SMITH, BECK and MERRES modification of GUTZEIT method was adapted. Arsine evolved from water residue is passed through capillary into tube containing roll of mercuric bromide paper, size and uniformity of stain facilitating comparison with standards. Range is from 0.002 to 150 γ arsenic. Ten to thirty γ arsenic per liter were found in surface and ground waters free from known abnormal arsenic contamination and no more in waters suspected of such contamination. For determination in mud, arsenic is distilled off as the trichloride, oxidized with perhydrol, precipitated with magnesia mixture, and weighed as magnesium pyroarsenate.—*Selma Gottlieb.*

Investigation of Vincent's Method for the Detection of Coli in Water. MUHIDDIN ALI. Arch. Hyg. Bakt., **109**: 1, 31–43, 1932. Method depends on growth of coli, but of no other water bacteria, at 41.5°C. in 1 percent peptone bouillon containing 0.5 percent sodium chloride and 0.083 percent phenol. It is as sensitive as EIJKMAN test for vigorous young cultures, but older ones are more sensitive to phenol, and method would not detect coli which had been in water some days. Effect of phenol varies with media; of those studied, inhibition of coli was least in 3 percent peptone broth. Some inhibition of growth was noted with beef extract media and no phenol.—*Selma Gottlieb.*

The Suitability of Lead and Copper Pipes for Conveying Drinking Water. G. NACHTIGALL. Gas- u. Wasserfach, **75**: 48, 941–9, 1932. Pure soft smelter lead is preferable to other forms of lead, or to coated lead, for pipes. City of Hamburg has studied aggressivity of local waters toward lead for many years, using piping and test pieces. Tests on new lead pipes showed, for example, average decrease from 2.15 p.p.m. lead for first 500 cc. drawn after nine hours standing during first month of use to 0.11 p.p.m. in twelfth month. Amount dissolved was greatest in first hours of standing. From first month on, practically lead-free water was obtained by running to waste slightly more water than volume of pipes. Removal of carbon dioxide and exclusion of air decrease amount of lead dissolved. With copper pipes, amount of metal dissolved increased during first few months and after one year reached from 3 to 5 p.p.m. in first portion drawn after nine hours standing. No cases of either lead or copper poisoning had been reported.—*Selma Gottlieb.*

The Filtration and Purification of Water as Adopted at Shepparton, Victoria, Australia. F. O. FURPHY. The Australian Municipal Journal, **12**: 151–154, September 30, 1932. Address before Waterworks Trusts Association. Supply, drawn from Goulburn River, is highly colored, with high bacterial counts accompanying reduced flow in summer, and with frequent unpleasant tastes and odors. Original treatment was confined to pumping and storage in elevated tank. Suspended matter is in such fine division that no appreciable sedimentation takes place within 24 hours. Addition of alum produces voluminous floc. Water is pumped from river through two single stage pumps, one 7-inch, of 55,000 gallons per hour (Imp.) capacity, and one 5-inch, of 35,000 gallons. Mixing basin is rectangular, 9 feet by 2 feet 6 inches by 7 feet deep. Alum is applied by dry-feed. Two sedimentation basins with total capacity 78,000 gallons (Imp.) give 1.5 hours detention. Daily flow is 1.25

m.g. (Imp.). Filters, 4 in number, are 15 feet by 7 feet 6 inches by 11 feet deep. Beds consists of 14 inches coarse gravel, ½- to ¼-inch, 6 inches of screened gravel between ¾-inch and 10-mesh; 6 inches screened sand between 10- and 20-mesh; 30 inches of screened sand between 20- and 30-mesh: total depth, 4 feet 8 inches. Collecting system consists of central pipe with many 2-inch laterals with ¾-inch perforations, all connected with float-controlled regulating valve. Each bed is back-washed once per day in summer and once every two days in winter. Chlorine is added in filtered water reservoir, which forms basement of plant, from which water is pumped to storage tank for distribution. Plant cost £9,640. Analyses of filtered water by public analyst show no turbidity, no solids, 12 p.p.m. chloride, 30-minute oxygen consumption, 3.3 p.p.m., alum 0.28 p.p.m., and free chlorine trace. In January 1932, with total pumpage, 31.75 m.g. (Imp.), cost per 1000 gallons (Imp.) included: alum, 0.23 d.; lime, 0.02 d.; chlorine, 0.25 d.; and electricity for pumping, 0.82 d. Total for alum and lime together in June was, however, 0.56 pence, due to heavier load of suspended solids. Plant was designed by A. Gordon Gutteridge, of Melbourne.—*E. B. Besselievre.*

Incrustation in Cast Iron Water Mains. W. R. WHITE. A. M. Inst. C. E., Australian Municipal Journal, 12: 202, October 31, 1932. Discussion of corrosion and internal incrustation as affecting carrying capacity. Internal deposits are classed as either (1) ferruginous, (2) calcareous, as from very hard "borehole" water, or (3) slimy, from organic matter. Importance of direct oxidation of pipe metal is stressed, while that of "iron bacteria" is minimized. Presence of pit under each incrusting nodule is referred to. Belief is expressed that quality of pipe material is important and that greater uniformity in structure of steel pipe as compared with cast iron, is of advantage. Steel pipes laid in Bloemfontein in 1904 show less internal corrosion than cast iron mains laid at same time, despite fact that coating of steel pipe did not seem superior to that of iron. Acid waters accelerate deterioration. No amount of pretreatment will entirely prevent corrosion in imperfectly protected pipes. Nodules rarely exceed one inch in height and this is offered as explanation of why engineers usually adopt pipes an inch greater in diameter than actually required. Removal of incrustation by scrapers of various types is usually followed by accelerated deterioration. Reliance should rather be placed on proper coating. Bitumen compounds proved more effective when applied cold than when applied hot. Scrapers designed for Bloemfontein and special spray nozzle for recoating pipe after scraping are described. In "Eric" method of recoating, developed in England, bituminous compound is electrically deposited. Entire system is pumped full of compound; electrical current is passed through; and excess compound pumped out. Method is suitable for mains of 6-inch diameter and under. Comparative costs of Bloemfontein method of scraping and spray recoating, as against excavating and recoating in field, show saving of 50 percent in favor of former method. Importance of care in selection of re-coating materials and plant, in supervision, and in application is stressed. It is believed that even should scraping not entirely remove all foreign material, yet by spray recoating, effect of missed spots is nullified, any oxide remaining absorbing the bituminous material down to metal itself.—*E. B. Besselievre.*

NEW BOOKS

Sixty-Sixth Annual Report of the Commissioners of Water Works in the City of Erie, Pa., for Year Ending December 31, 1932. 79 pp. Tabulations are given showing detailed data regarding operation and financing of Erie water works during 1932. Daily average consumption was nearly 19 million gallons, equivalent to 158.15 gallons per capita by population of 120,000, or, exclusive of industrial and commercial use, to 98.28 gallons. Cost of collecting, purifying, and delivering water was $32.389 per m.g. Gallons pumped per pound of coal averaged 347.85. Net addition of $23,432.85 was made to surplus during year and water to value of $58,074.52 was supplied without cost to city for municipal purposes. Data include for each plant separately monthly totals and averages covering chemical consumption and quality of raw and filtered water. New West plant was placed in operation on July 1. Alum dosages averaged 0.269 and 0.276 grain per gallon, respectively, and chlorine applied, 1.55 and 2.10 pounds per m.g. Ammonia was applied at Chestnut Street plant only, at rate of 1.04 pounds per m.g. for taste prevention. Wash water consumption averaged 2.75 and 1.49 percent at old and new plants, respectively. Analytical data include monthly average bacterial counts, turbidity, alkalinity, and color of raw and filtered waters, average temperature, and results of *B. coli* tests. No positive *B. coli* results (10 and 1 cc.) were obtained from filtered water at either plant. Appended to report is brief description of works and schedule of water rates.—*R. E. Thompson.*

Annual Report of Department of Waterworks and Street Lighting, Topeka, Kansas, 1932. Separate, 64 pp. Embodying individual reports of G. D. PELTON, Department Engineer, D. H. RUPP, Filtration Engineer, and H. F. CHUTE, Cashier. Water works system is outlined and operating and financial data are given in tabular and graphical form in great detail. Supply is obtained from Kansas River and from 3 large dug wells. System consists of an aërator, settling basins, 4 roughing filters with total capacity of 16 m.g.d., 8 rapid sand filters with nominal total capacity of 8 m.g.d., 2-m.g. clear well, low- and high-lift pumps, and 10-m.g. reinforced concrete distribution reservoir. Complete pitometer survey of system conducted during year disclosed leakage and under-registration of large meters amounting to 546,000 gallons daily; with prospective annual saving of $23,680. Population served was 67,005, 3,000 being outside city limits, and average daily consumption, 4,349,000 gallons, equivalent to 65 gallons per capita. All services are metered. Water delivered through meters totaled 63.8 percent of water pumped: public use is estimated at 15 percent, balance being attributable to under-registration, unavoidable main leakage, fire fighting, and unaccounted for waste, which last is estimated at 4.28 percent. Costs of pumping and purification, including depreciation, were $33.71 and $25.05 per m.g., respectively. Total cost of supplying water, including interest, retirement of bonds, sinking fund, etc., was $236.30 and total net revenue received, $251.84 per m.g. Rates vary from 45 cents per 1000 gallons for the first 1000 cubic feet to 12 cents per 1000 for all over 20,000 cubic feet, with minimum bill of 40 cents per month. Alum is employed for clarification; lime and soda ash, for softening; chlorine (prior to

filtration), for disinfection; and ammonia, or ammonium sulfate, and carbon, for taste prevention. Purification plant operating data are given in great detail, including amounts and costs of chemicals used, chemical and bacteriological quality of water before and after treatment, cost of softening, cost of coagulants per unit of turbidity removed, etc. Notable economies have been effected in the cost of purification, average chemical cost during past 3 years being only 86 percent of former average, despite fact that an average of 19 percent more water was treated per year and 52 percent more turbidity and 36 percent more hardness removed. During 1932, turbidity was reduced from average of 1650 p.p.m. to 0, total hardness from 239 to 83 p.p.m., bacterial count at 37° from 2670 to 12 per cc., and *B. coli* index per 100 cc. from 13,345 to 0. Interesting feature of report is condensed summary of purification plant operation data which is reprinted for general distribution.—*R. E. Thompson.*

Vom Wasser; Ein Jahrbuch für Wasserchemie und Wasserreinigungstechnik. VI. Band: 1932. 262 pp. Verlag Chemie, G.M.B.H., Berlin W. 10. **Mineral Springs.** A. PAQUET and L. FRESENIUS. 9–58. Numerous descriptive examples, with 58 illustrations, are given to show that Rhineland is densely punctured with mineral springs and wells, each having its own name, character, potency, and curative effect. Latter part of article is a commentary on the various wells and springs and explanatory notes on them are given. **Rate of De-acidification of Water Containing Carbon Dioxide by Means of Marble.** J. TILLMANS, P. HIRSCH and A. ESCHENBRENNER. 59–91. Physico-chemical study of velocity of reaction between calcium carbonate, carbon dioxide, and calcium bicarbonate. Water at definite temperature containing a standard amount of carbon dioxide was passed at definite speed through marble (sieved to definite sizes) contained in siphon apparatus, free and combined carbon dioxide being determined ar regular intervals. Speed of reaction was found to be independent of shape of filter: time taken to effect removal of carbon dioxide was inversely proportional to mass of filtration marble. Other factors studied were size of filter particles; effect of mixture of particles of different sizes, such as would be met with under practical conditions; and variations of temperature between 6 and 27°C, which had a considerable effect upon reaction velocity. Carbon dioxide removal was independent of motion of water in filter. **Importance of Routine Chemical, Bacteriological and Biological Examinations of Water Supplies in Town and Country.** H. BACH. 92–103. Survey of value of systematic water examination giving also essentials of pure drinking water. Where any possibility of contamination arises and where purification is effected by media like chlorine value of bacteriological examination is stressed. Physical examination is valuable because first desiderata in glass of water are clarity, absence of floating particles, and freedom from unnatural color and smell. Chemical analysis is essential for information on dissolved matter. Biological examination of fauna and flora is of particular value for upland surface water. Value of water works laboratories is stressed; water examination should begin at intake and be continued through all stages until it reaches consumer. **Removal of Unpleasant Tastes from Drinking Water.** H. BACH. 104–122. Tastes may occur from natural causes without sewage access, e.g. "fishy" taste due to algae. Industrial

waste or town sewage may cause phenolic tastes, especially in connection with chlorination; smoke-laden air, depending on its phenol content, may give, particularly with chlorinated water, so-called "medicinal taste," which is sometimes associated with security. Methods of removal include (1) aëration by spraying or by compressed air for volatile compounds; (2) destruction by excess chlorine, followed by dechlorination with sulphurous acid, thiosulphate, or active carbon; (3) preventive measures, e.g. addition of ammonia before chlorine, use of chloramine, destruction of algae with copper sulphate or with chlorine, treatment of water with permanganate or with hydrogen peroxide; (4) adsorption, as by sand filtration, precipitation by alum, or other coagulant; or by treatment with active carbon either by filtration through granular bed, or by addition of powdered carbon before rapid filtration. This last appears to be standard method in United States. **Experiments on Water Sterilization with Cerium Preparations.** W. OLSZEWSKI. 123–124. Water containing 225 organisms per cc. on agar and *B. coli* in 0.01 cc. was treated with soluble salts of cerium, or with cerium and other rare earth mixtures in varying amounts. Sterilizing effects were obtained, e.g. reduction to 10 organisms per cc. on agar, and to *B. coli* in 0.1 cc. **Preparation of Radium Baths.** W. PRÉE. 125–126. With increasing production of radium, artificial radium baths are now possible. Apparatus called "Emanator," containing radium preparation, is used to charge water. Dosing is controlled by measuring radio-activity of treated water. Details are given of preparation of radium baths at Dresden municipal bathing establishment. **Conditioning and Testing of Water for Technical Use.** E. NAUMANN. 127–138. Characteristics of water needed for cooling purposes, various food industries, ice factories, beer and spirits, sugar industry, textile trade, paper making, and photographic work are given. Minerals, harmful or valuable, which may occur are mentioned in each case; e.g., types of water best suited for various varieties of beer; necessity of iron- and manganese-free water for textile work, photographic work, and paper making is stressed. Conditioning may involve sedimentation, flocculation, and filtration. Organisms can be removed by chlorine, ozone, or Katadyn sand, while taste and smell are removed by flocculation or active carbon. De-acidification is effected by aëration, passage through marble, or addition of chalk, or of soda-ash; hardness is dealt with by heat, lime and soda-ash, or base exchange, while manganese and iron are removed by aëration and filtration, or by lime, alum, or permanganate. Removal of very soluble salts is more difficult and costly and is effected by distillation or electro-osmosis. Necessity for analytical control throughout is emphasized. **History of Feed Water Treatment.** F. C. GAISSER. 139–145. Application of chemical analysis to water was important event in history of water chemistry; knowledge gained served as method of attack on problem of boiler scale and necessity of regular and frequent analyses became manifest. Literature shows that there is scarcely a medium now recommended which has not been in use before. By 1850, soda had received considerable attention. Since 1810, not less than 180 different groups of materials have been patented for boiler use, those most used being soda, barium chloride, hydrochloric acid, and ammonia. Boiler scale preventives may be grouped as (1) mineral materials and salts, (2) organic material, and (3) mixtures of inorganic and organic materials. **Ultra-micro-**

scopic Observations for the Valuation of Water. K. HOFER. 146–154. Characteristics of particles of different sizes in water are dealt with. Hydrated colloids, i.e., those surrounded by a film of water, appear in ultramicroscope as faintly luminous specks. Ultramicroscope cannot replace methods involving ultrafiltration; but it reveals whether flocculation is adequate, whether chemical softening is complete, and whether traces of coagulants remain in colloidal suspension. Illustrations are given of colloid produced by permanent hardness in presence of trisodium phosphate and of residual alumina after treatment. Probability of foaming in boiler water can be predicted from particle size. Illustrations of typical waters are given. **A Simple Colorimeter for Water Investigations.** R. CZENSNY. 155–167. Simple form of colorimeter is described, permanent standards being sealed in test tubes and placed in rows on wooden block with white partition for color comparison. Standards are prepared from colored inorganic salts; data for their preparation and use in nitrate, ammonia, iron, sulfate, and nitrite determinations are given. In pH determinations thymol blue, methyl orange, and bromcresol blue are used for low values (1.6–5.0), while for higher values thymolphthalein (8.2–9.4) and salicyl yellow (10.0–12.0) are recommended. **Feed Water in High Pressure Systems.** LIST. 168–202. Work of HALL in America on solubilities of calcium sulphate and carbonate and on prevention of gypsum precipitation by maintaining suitable carbonate:sulfate ratio is considered. Formation of scale is explained on colloidal-chemical theory of HALL, STUMPER, and HOFER. On account of carbonate hydrolysis at high temperatures, use of sodium phosphate is advocated for pressures exceeding 15 atmospheres. Foaming is not caused by high salt concentration alone, nor by suspended matter alone, but by combination of factors; in particular, film of sufficient viscosity and stability must form over surface; colloidal stabilisers prevent this, by maintaining boiler salts in colloidal state. Influence of pressure on carbonate:sulfate ratio is dealt with; for high pressures 1:3 ratio should not be exceeded. In corrosion, most important factors are oxygen and carbon dioxide; it is minimized by keeping pH value of water at 9.5. Corrosion is also caused by reaction between iron and steam, starting at 300° and proceeding destructively by 600°. Modern water treatment comprises removal of hardness to greatest possible extent, complete degasification, utmost possible reduction of salt content, and maintenance of protective alkalinity, with simultaneous presence of sodium sulphate and sodium phosphate. Most important part of purifying apparatus is filtering plant and influence of temperature on clarification should be noted; optimum temperature seems to be 70°, at which clarity is attained in 1½–2 hours. **Practical Problems of Boiler Feed Water Treatment.** A. SPLITTGERBER. 203–216. Condition of boiler working at 50 atmospheres with acid moorland water with pH value of 5.9 to 6.9 is described. Scale from 2 to 3 centimeters thick containing 95 per cent of iron oxide formed on boiler drums. Attack could be stopped by neutralizing with soda lye, and organic matter will in future be removed by alum treatment. Experiments with trisodium phosphate for scale prevention and removal proved it to be most suitable alkaline reagent. Although it prevents formation of new scale, it does not always break up old scale; nor can it be recommended for complete softening owing to its cost. Presence of ex-

cess phosphate allows "alkali number" to be reduced from 100 to 400, but phosphate cannot replace sulfate to prevent embrittlement. **Phosphoric Acid Estimation in Feed Water.** H. HAUPT and W. C. SCHROEDER. 217–223. Gravimetric, volumetric, and colorimetric methods are considered, colorimetric being most useful. Reduction of phospho-molybdate by 1,2,4-aminonaphthol sulphonic acid yields best results; experimental procedure is given. Maximum blue color does not develop until after five minutes. Chlorides, nitrates, sulphates, silicates, and iron have no effect at concentrations usual in boiler water. Method can be used for phosphate concentrations of between 3 and 100 milligrams per litre. Blue color is directly proportional to phosphate concentration. **Manufacture of Trisodium Phosphate.** H. MENGELE. 224–227. Three methods are used: (1) phosphoric acid obtained from calcium phosphate with sulfuric acid is neutralized with soda and resulting disodium hydrogen phosphate treated with caustic soda; (2) aluminum phosphate, or mixture of calcium phosphate and bauxite, is fused with soda or with sodium sulfate and coal, the cold mass lixiviated, and the triphosphate crystallized; (3) phosphor-iron and sodium sulfate are heated to high temperature, giving trisodium phosphate and iron sulfide. **Decomposition of Calcium and Magnesium Sulfates with Sodium Carbonate, Sodium Hydroxide, and Calcium Hydroxide.** J. LEICK. 228–242. Reaction between calcium sulfate and sodium carbonate is practically uninfluenced by time factor, while influence of temperature falls with increasing concentration. For reduction of residual hardness, excess of 2 millivals of soda is best. Reaction between sodium carbonate and magnesium sulfate is very incomplete because of basic carbonate formation; excess soda and longer reaction time are without appreciable effect. Reaction between calcium sulfate and sodium carbonate at low temperatures is much retarded by presence of magnesium sulfate. Reaction between magnesium sulfate and sodium hydroxide is fairly complete and hydroxide excess of 0.5 to 1.0 millivals with a magnesium content of 0.15 to 0.20 millivals gives best results. Reaction temperature is of subordinate importance. **Investigation of the Water of the Limmat.** E. WASER and W. HUSMANN. 243–251. Quality of water in river Limmat assumed importance in 1932 in consequence of establishment of manufactures in district. Samples were taken at different hours on different days from 10 given points on river. Usual physical and chemical analysis gave information as to load of sediment etc. at various times, while biological and bacteriological examinations were conducted at same time. Work will be carried on and completed during present year. **Estimation of Water Impurities by the Filter Plate Process.** F. SIERP. 253–260. Suspended matter is filtered by means of a perforated filter plate and suction pump on to a 7 cm. filter paper and its amount deduced, roughly quantitatively; it can also be further examined microscopically. For approximating pollution of streams and efficacy of settling plants, method is suited, but not for trade wastes containing mainly dissolved impurities; it is intended only to supplement, and not to replace, chemical analysis. **Fish Mortality in Acid Water.** H. HAUPT. 261–262. Investigation of water in large aquarium was made, owing to death of fish. Chief point of interest in analysis, which is given, is pH value of 4.3. It was considered that death was due to destruction of blastoderm of fish, due to acidity, which led to their suffocation.—*W. G. Carey.*

Correction

Please read Abstract as follows instead of as it appeared in June number, at p. 900 (THIS JOURNAL, **25**: 6, 900):

The Selection of a Dilution Water for Bacteriological Examinations. C. T BUTTERFIELD. Jour. Bact., **3**: 355, 1933. As shown by previous studies of B. O. D. determination, need for controlled water for bacteriological dilution is apparent. Distilled water should not be used, since it inhibits about 40 per cent of colonies when results are compared with immediate plating and after standing 15 to 30 minutes. Either synthetic phosphate water, or buffer water known as Formula C, gives best results. Sterilization should be conducted in resistance glass only, of pyrex grade, and all control determination, pH, etc., should be made after sterilization. Final pH of water after sterilization should not exceed 8.2 to give consistent results and, if growth without lag is desired, it should not be above 7.5. A value of 9.0 is bactericidal. This study shows conclusively that presence of minerals in dilution waters is necessary. Formulas for preparation of such waters are given, with recommendation that the phosphate be used, because of its simplicity of preparation.—*Edw. S. Hopkins.*